Shuttle Ground Operations Efficiencies/Technologies Study

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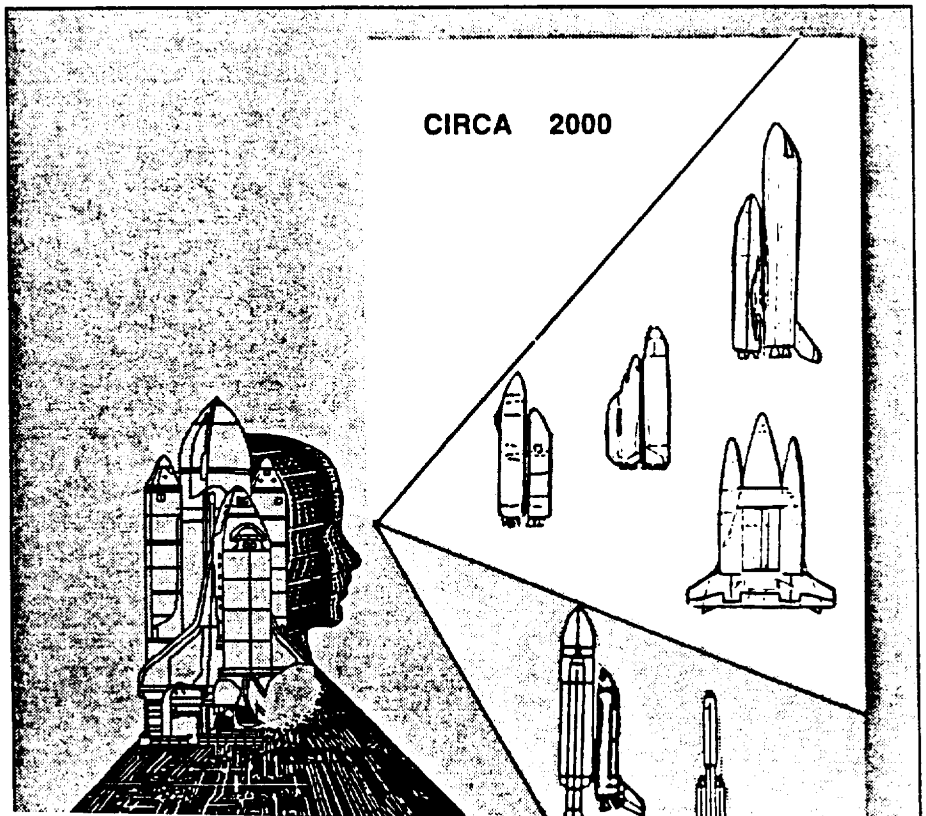

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FINAL REPORT PHASE 2
Volume 4 of 6

SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA

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SHUTTLE GROUND OPERATIONS EFFICIENCIES / TECHNOLOGIES STUDY

PHASE 2 FINAL REPORT

STUDY REPORT

Volume 1	Executive Summary	
Volume 2	Final Presentation Material	
Volume 3	Space-vehicle Operational Cost-drivers Handbook (SOCH)	
	Part 1	Cost Driver Checklists
	Part 2	SOCH Reference Information
Volume 4	Simplified Launch System Operational Criteria (SLSOC)	
Volume 5	Technology References	
Volume 6	Circa 2000 System	

Volume 1 EXECUTIVE SUMMARY

The Executive Summary provides an overview of major elements of the Study. It summarizes the Study analytic efforts, the documentation developed, and reviews the recommendations resulting from the analyses conducted during Phase 2 of the Study.

Volume 2 PHASE 2 FINAL ORAL PRESENTATION

The Final Presentation Material volume contains the charts used in the Final Oral Presentations for Phase 2, at KSC on April 6, 1988. A brief, overall review of the Study accomplishments is provided. An indepth review of the documentation developed during the last quarter of Phase 2 of the Study is presented. How that information was used in this Study is explained in greater detail in Vols. 3 and 4. An initial look at the topics planned for the upcoming Workshops for Government/Industry is presented along with a cursory look at the results expected from those Workshops.

Volume 3 SPACE-VEHICLE OPERATIONAL COST DRIVERS HANDBOOK (SOCH)

The Space-vehicle Operational Cost drivers Handbook (SOCH) was assembled early in Phase 2 of the Study as one of the fundamental tools to be used during the rest of the Phase. The document is made up of two parts -- packaged separately because of their size.

Part 1 Presents, in checklist format, the lessons learned from STS and other programs. The checklist items were compiled so that the information would be easily usable for a number of different analytical objectives, and then grouped by disciplines or gross organizational, and/or functional responsibilities. Content of the checklists range from 27 management; 11 system engineering; 8 technology; and 19 design topics -- with a total of 793 individual checklist items. Use of this Handbook to identify and reduce Cost Drivers is recommended for designers, Project and Program managers, HQ Staff, and Congressional Staffs.

Part 2 Contains a compilation of related reference information about a wide variety of subjects including ULCE, Deming, Design/Build Team concepts as well as current and previous space launch vehicle programs. Information has been accumulated from programs that range from, Saturn/Apollo, Delta, Titan, and STS to NASP and Energia.

Volume 4 SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA (SLSOC)

The SLSOC document was developed from the generic Circa 2000 System document, Vol. 6; is similar in content; and also indicates the manpower effect of the elimination of many STS-type cost drivers. The primary difference between the two documents is the elimination of all generic Circa 2000 requirements (and support) for manned-flight considerations for the ALS vehicle. The data content of the two documents, while similar in nature, was reorganized and renumbered for SLSOC so that it could be used as the basis for various panels and subpanels in an ALS Workshop.

PHASE 2 STUDY REPORT (Cont'd)

Historical data is the basis for the conclusion that incremental improvements of technology and methods cannot significantly improve LCC (by an order-of-magnitude) without major surgery. A system enabling the development of a radically simplified operational concept, reflected in SLSOC, was included so that proposed designs (and operations) could be compared to systems providing for simplicity -- rather than the current STS complexity.

The identified operational cost drivers from STS plus other historical data were used as background reference information in the development of each example concept designed to eliminate cost drivers. These example concepts, when integrated, would support an order-of-magnitude cost reduction in current (STS), exorbitant Life Cycle Costs (LCC). Individual operational requisites were developed for each element in the associated management systems, integration engineering, vehicle systems, and supporting facilities. These have associated rationale, sample concepts, identification of technology developments needed, and technology references to abstracts. The technology abstracts are provided in a separate volume, Vol. 5.

Technology changes almost daily, thus past trade studies may no longer be valid. In addition, old "trades" often used inaccurate estimates of "real" operational costs. Vehicle designs are compromises and have been performance oriented with operations methods/techniques based on those designs. It is the intent of our example concepts in the SLSOC to stimulate design teams to improve or replace conventional design approaches. Obviously, it is up to the responsible program design teams to provide design solutions to resolve operational cost drivers.

Volume 5 TECHNOLOGY REFERENCES

This document provides a repository for the Technology References for the SLSOC and the CIRCA 2000 System documents. The technology references, mostly from NASA RECON, are supplied to the reader to facilitate analysis on either the SLSOC or the CIRCA 2000 System documents. Some data references were also obtained via DIALOG. If more technical information is desired by an analyst, he must obtain the additional documentaiton thru his library or from some other appropriate source. The XTKB (EXpanded Technology Knowledge Base) provided a user-friendly tool for our analyses in identifying and obtaining the computerized database reference information contained in this document. Thousands of abstracts were screened to obtain the 300 plus citations pertinent to SLSOC in this Volume.

Volume 6 CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

The Circa 2000 System Operations Requirements were developed using STS as a working data source. We identified generic operations cost drivers resulting from performance-oriented vehicle design compromises and the operations methods/techniques based on those designs. Those Cost Drivers include high-cost, hazardous, time & manpower-consuming problem areas involving vehicles, facilities, test & checkout, and management / system engineering. Operational requisites containing rationale, example concepts, identification of technology developments needed, and identification of technology references using available abstracts were developed for each Cost Driver identified. Elimination of cost drivers significantly reduces recurring costs for prelaunch processing and launch operations of space vehicles.

NOTE: Volumes 1,3,4 and 5 are being widely distributed. Volume 2 is a copy of presentation material already distributed and Volume 6 will be distributed only on request. Copies of the full report will be placed in libraries at NASA HQ., JSC, KSC, MSFC and NASA RECON. Individual volume copies may be obtained by forwarding a request to W. J. Dickinson, KSC PT-FPO, (407) 867-2780.

TABLE OF CONTENTS

SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA

Page

Shuttle Ground Operations Efficiencies/Technologies Study
Phase 2 Final Report Overview ---------------------------------- i
Table of Contents -- iii
Acronyms and Abbreviations ------------------------------------ v

1.0 INTRODUCTION --- 1
Figure 1.0-1 SLSOC Interrelated Alternatives ----------------- 4
Figure 1.0-2 Simplified Launch System Operational Criteria --- 5

2.0 SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA (SLSOC)

2.1 MANAGEMENT AND SYSTEM ENGINEERING ---------------------- 7

Procurement (M1) --------------------------------------- 11
Design / Build Teams (M2) ------------------------------ 12
Deming-Style Management (M3) --------------------------- 13
Life Cycle Costs (LCC) (M4) ---------------------------- 14
Design to Cost (M5) ------------------------------------ 15
Unified Life Cycle Engineering (ULCE) (M6) ------------- 16
Risk Management (M7) ----------------------------------- 17
Reliability / Operability (M8) ------------------------- 18
Maintainability / Supportability (M9) ------------------ 19
Logistics Support (M10) -------------------------------- 20
Operationsal Test Requirements (M11) ------------------- 21
Quality Assurance (M12) -------------------------------- 22
Safety (M13) --- 23
Security (M14) --- 24
Connectivity Architectures (M15) ----------------------- 25

2.2 AVIONICS AND SOFTWARE ---------------------------------- 27

Autonomous Vehicle
Bit/Bite (On-Board Checkout) (A1) ---------------- 31
Fault Tolerant Avionics Suite (A2) --------------- 32
Autonomous GN&C (A3) ----------------------------- 33
No Hardwire to Vehicle;
Min. Launch Control Interface;
No Ground Power (A4) ----------------------------- 34
Software
Software Commonality (A5) ------------------------ 36

2.3 POWER -- 37

Eliminate Requirement for Ground Power (E)-------------- 40
Low Maintenance Energy Storage;
Propellant Grade Fuel Cells;
State-of-Art Energy Sources;
System Sized to Provide On-Board Power
for Ground Operations

2.4 STRUCTURES & MATERIALS ---------------------------------- 43

Improved Structure
High Strength, Light Weight Cryo Tanks (S1) ------ 47
Structural Integrity Verification (S2) ----------- 48
Integral TPS (S3)--------------------------------- 49

TABLE OF CONTENTS
(Continued)

2.4 **STRUCTURES & MATERIALS**

Ordnance
No Ordnance (S4) ---------------------------------- 50
Independent Weapon Destruct (S4.1) --------------- 51
Laser Ignition (S4.2) ---------------------------- 52
Non-pyrotechnic Seperation
(Acceleration/Clevis Separation) (S4.3) --------- 53

2.5 **PROPULSION** -- 55

Integrated Propulsion System
Simplified Robust Propulsion System (P1) --------------- 59
Fully Throttleable Engines (Multi-phase) (P1.1) -------- 60
Soft Engine Start (P1.2) ------------------------------- 61
TVC by Delta Thrust and/or RCS /or Aero (P1.3) --------- 62
One Oxidizer / One Fuel (P1.4) ------------------------- 63
Eliminate Separate OMS and RCS (P2) -------------------- 64
Eliminate High-Maintenance Turbopumps (P3) ------------- 65
No Hydraulics (P4) ------------------------------------- 66
No Hypergols (P5) -------------------------------------- 67
No GN2/He On-board Purges (P6) ------------------------- 68
No GN2/He Pressure Systems (P7) ------------------------ 69
No Gimballed Engines (P8) ------------------------------ 70
No Extensive Recovery & Refurbishment (P9) ------------- 71

2.6 **FACILITIES AND SUPPORT EQUIPMENT** --------------------- 73

100% Computer Connectivity (L1) ------------------------------ 77
Automation
Automated Electronic OMI's (L2) ------------------------ 78
Text and Graphical Data Acquisition (L3) --------------- 79
Automatic Test Requirements Verification (L4) ---------- 80
Stage Assembly
Final Stage Assembly at Launch Site (L5) --------------- 81
Horizontal Processing; Horz. Transport L6) ------------- 82
Horizontal Transport of Individual Stages to Pad (L7)-------- 84
Barren Pad (L8) -- 86
Deep Water Exhaust Buffer (L8.1) ----------------------------- 87
Flyaway Connects Only - No Retracting Umb. Carrier Plates-(L8.2) 88
No Swingarms (L8.3) -- 89
No Vehicle or Payload Access Structure (L8.4) ---------------- 90
Simplified Holddown/release (L8.5) --------------------------- 91
No Deluge or Sound Suppression Water (L8.6) ------------------ 92
No Pad ECS (L8.7) -- 93
Erect / Mate Stages at Pad (L9)------------------------------- 94
Payloads: Standard Autonomous Cargo Container (L10) ---------- 95

3.0 **SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CONCEPT** ---------------- 97
(To be completed during Phase 3)

3.1 Advanced Launch Systems Goals and Requirements
3.2 Flight Vehicle Concept and Rationale
3.3 Facilities/ GSE/ Processing Concept and Rationale
3.4 SLSOC vs. LCCV; a Comparison
3.4.1 Processing Manpower and Schedules
3.4.2 Cost Factors
3.5 Conclusions

4.0 **STS / KSC GROUND SUPPORT FACILITIES AND HEADCOUNT**
(To be completed during Phase 3)

ACRONYMS and ABBREVIATIONS

$B	Dollars-billions
$M	Dollars-millions
AFD	Aft Flight Deck
AFSATCOM	Air Force Satellite Communications
AFSCF	Air Force Satellite Control Facility
AFSCN	Air Force Satellite Control Network
AFSCF/STC	Air Force Satellite Control Facility/Space Test Ctr.
AGCS	Automatic Ground Control System
AH	Ampere-Hour
AI	Artificial Intelligence
Al	Aluminum
Al-Li	Aluminum-Lithium
AOA	Abort Once Around
APU	Auxiliary Power Unit
ASE	Airborne Support Equipment
ASSY	Assembly
ATC	Air Traffic Control
ATE	Automatic Test Equipment
ATKB	Automation Technology Knowledge Base
ATO	Abort to Orbit
ATPG	Automatic Test Program Generation
A50	Aerozine 50 (50% Hydrazine and 50% VDMH)
BIT	Built-In-Test
BITE	Built-In-Test-Equipment
BSTR	Booster
C	Celsius; Carbon
C2K	Circa 2000
C_3H_8	Propane
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAI	Computer Aided Instruction
CALS	Computer Aided Logistics System
CAM	Computer Aided Manufacturing
CDDT	Countdown Demonstration Test
CDF	Confined Detonating Fuse
CECO	Center Engine Cutoff
CELV	Complimentary Expendable Launch Vehicle (now Titan IV)
CG	Center of Gravity
CH_4	Methane
CIM	Computer Integrated Manufacturing
CITE	Cargo Integration Test Equipment
CIU	Computer Interface Unit
CM	Command Module
C/O	Checkout
COMM	Communications
COMM SAT	Communication satellite
CPU	Central Processing Unit
CPV	Combined Pressure Vessel
CR	Control Room
Cryo	Cryogenic
CSOC	Consolidated Space Opertions Center
CT	Crawler Transporter
CTS	Common Tank Set
CV	Cargo Vehicle
CVD	Chemical Vapor Deposition

ACRONYMS and ABBREVIATIONS
(Continued)

DA	Data Acquisition
D/A	Digital/Analog
DAS	Data Acquisition System
DB	Data Base
DBMS	Data Base Management System
DBS	Direct Broadcast Satellite
DBT	Design Build Team
dc	Direct Current
DCA	Defense Communications Agency
DDT&E	Design, Development, Test and Evaluation
DFT	Design For Testability DMS Data Management System
DOD, DoD	Department of Defense
DOMSAT	Domestic Communication Satellite
DPS	Data Processing System
DR	Discrepancy Report
DSCS	Defense Satellite Communication System
DSN	Deep Space Network DSP Defense Support Program
DTC	Design to Cost
ECLSS	Environmental Control & Life Support System
ECS	Environmental Control System
EECOM	Electrical, Environmental, Communications
EIU	Engine Interface Unit
ELS	Eastern Launch Site
ELV	Expendable Launch Vehicle
EMC	Electro Magnetic Compatibility
EMU	Extra-vehicular Mobile Unit; Extended Memory Unit
EPD&C	Electrical Power Distribution and Control
EPS	Electrical Power Subsystem
ES	Expert System
ESS	Energy Storage System
E/T	External Tank
ETR	Eastern Test Range
EVA	Extra Vehicular Activity
FAA	Federal Aviation Administration
FCE	Flight Crew Equipment
FCM	Fuel Cell Module
FDO	Flight Dynamics Officer
FMS	Flight Management System
FRCS	Forward Reaction Control System
FSS	Flight Systems Simulator
FWC	Filament Wound Case
FY	Fiscal Year
GB	Ground Based
GD	General Dynamics
GEO	Geosynchronous Orbit
GFS	Government Furnished Support
GH2, GH_2	Gaseous Hydrogen
GLOW	Gross Liftoff Weight
GN&C, (G&C)	Guidance Navigation and Control
GN_2	Gaseous Nitrogen
GO	Ground Operations
GO2, GO_2	Gaseous Oxygen
GPM	Gallons Per Minute
GPS	Global Positioning Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

ACRONYMS and ABBREVIATIONS
(Continued)

GSTDN(STDN)	Ground Station Tracking and Data Network
HC	Hydrocarbon
He	Helium
HEO	High Earth Orbit
HIF	Horizontal Integration Facility
HLLV	Heavy Lift Launch Vehicle
HPFTP	High Pressure Fuel Turbo Pump
HTO	Horizontal Take Off
H/W	Hardware
H_2	Hydrogen
HYD	Hydraulic(s)
IC	Integrated Circuit
IDSS	Integrated Design Support System
I/F	Interface
IMIS	Integrated Maintenance Information System
IFA	In-flight Anomaly
ILS	Integrated Logistics System
IMU	Inertial Measurement Unit
INCO	Instrumentation and Communications Officer
INEL	Idaho National Engineering Laboratory
INS,INST	Instrumentation
INT	Integration
IOC	Initial Operational Capability
I/O	Input/Output
IPR	Interim Problem Report
IPV	Individual Pressure Vessel
IR	Infrared
IR&D	Independent Research and Development
IRR	Internal Rate of Return
Isp	Specific Impulse
IU	Interface Unit
IUS	Inertial Upper Stage
JSC	Johnson Space Center
K	Thousand
KEW	Kinetic Energy Weapon
KSC	Kennedy Space Center
KW	Kilowatt
LAN	Local Area Network
LBS	pounds
LCA	Launch Control Amplifier
LCC	Life Cycle Cost
LCCV	Low Cost Cargo Vehicle (MMC)
LCE	Low Cost Expendable
LCEP	Low Cost Expendable Propulsion
LC-Titan	Large Core Titan
LDC	Large Diameter Core
LEM	Lunar Excursion Module
LES	Launch Escape System
LEO	Low Earth Orbit
LH	Left Hand
LH2,LH2	Liquid Hydrogen
$Li\text{-}SOCl_2$	Lithium Sulphur Oxygen Chlorine
Li	Lithium
LN_2	Liquid Nitrogen
LO2,LO_2	Liquid Oxygen

LPS	Launch Processing System
LRBs	Liquid Rocket Boosters
LRE	Liquid Rocket Engine
LRU	Line Replaceable Unit
LSC	Linear Shaped Charge
LV	Launch Vehicle
L&L	Launch and Landing
M	Million
MC	Mission Control
MCC	Main Combustion Chamber
MCR	Modification Change Request
MCS	Mission Control System
MCT	Mission Control Teams
MDAC	McDonnell Douglas Astronautics Company
MDM	Multiplex/De-multiplex
ME	Main Engine; Maintenance Expert
MELV	Medium Expendable Launch Vehicle
MEO	Medium Earth Orbit
MFRCV	Manned Fully Reusable Cargo Vehicle(s) (STS II)
MFRGB	Manned Fully Reusable Ground Based-OTV
MFRSB	Manned Fully Reusable Space Based-OTV
MILSTAR	Military Transmission and Relay Satellite
MLP	Mobile Launcher Platform
MMC	Martin Marietta Company
MMMA	Martin Marietta Michoud Aerospace
MMU	Manned Maneuvering Unit
MPM	Manipulator Positioning Mechanism
MPRCV	Manned Partially Reusable Cargo Vehicle
MPS	Main Propulsion System
MPSR	Multipurpose Support Room
MPST	Multipurpose Support Team
MSBLS	Microwave Scanning Beam Landing System
MSFC	Marshall Space Flight Center
MS/NAS	Machine Screw/National Aircraft Standard
MTBF	Mean-Time Between Failure
MTTR	Mean-Time to Repair
NaS	Sodium Sulphur
NAS	National Airspace System
NA-S	National Aircraft Standard
NASA	National Aeronautics and Space Administration
NASA/RECON	Remote Console (NASA information retrieval system)
NCCS	Network Communication and Control Stations
NCS	Network Control Stations
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Test
Ni-Cd	Nickel-Cadmium
NiCad	Nickel Cadmium
NIH	Not Invented Here
$Ni-H_2$	Nickel-Hydrogen
NiTi	Nickel-Titanium
Nitinol	Nickel-Titanium-Naval Ordnance Laboratory
NLG	Nose Landing Gear
NORAD	North American Air Defense
NSI	NASA Standard Initiator
N_2H_4	Hydrazine Monopropellant
N_2O_4	Nitrogen Tetroxide

ACRONYMS and ABBREVIATIONS
(Continued)

OAA	Orbiter Access Arm
OBECO	Outboard Engine Cutoff
O&M	Operations and Maintenance
OMI	Operations and Maintenance Instruction
OMP	Operation Maintenance Plan
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OMV	Orbital Maneuvering Vehicle
OPC	Operations Planning Center
OPF	Orbiter Processing Facility
OPS	Operations
ORB	Orbiter
ORU	Orbiter Replacement Unit; Orbital Repaired Unit
OTV	Oribital Transfer Vehicle
OV	Orbiter Vehicle
P/A	Propulsion/Avionics Module
PAM	Payload Assist Module; Payload Applications Module
PAREC	P/A Recovery Area
PC	Printed Circuit
PCBS	Printed Circuit Boards
PCP	Power Control Panel
PCR	Payload Changeout Room
PDI	Payload Data Interleaver
PDR	Preliminary Design Review
PFLB	Pressure Fed Liquid Booster
P/FRCV	Partially/Fully Reusable Cargo Vehicle
PGHM	Payload Ground Handling Mechanism
PGOC	Payload Ground Operations Contractor (MDAC)
PIC	Pyro Initiator Controller
PIDB	Preliminary Issues Database
PL, P/L	Payload
PLB	Payload Bay
PLF	Payload Fairing or Payload Facility
POCC	Payload Operations Control Center
POI	Product of Inertia
PR	Problem Report
PRCBD	Program Review Control Board Directive
PRSD	Power Reactant Storage and Distribution
PSA	Payload Support Avionics
PSI	Pounds Per Square Inch
PSP	Processing Support Plan
PV	Present Value
PV&D	Purge, Vent and Drain
QA	Quality Assurance
QC	Quality Control
QD	Quick Disconnect
RADC	Rome Air Development Center
RAMCAD	Reliability and Maintainability through Computer Aided Design
RCC	Reinforced Carbon Carbon
RCS	Reaction Control System
R&D	Research and Development
RECON	Remote Console (NASA information retrieval system)
RF	Radio Frequency
RFCS	Regenerative Fuel Cell System
RFP	Request for Proposal

ACRONYMS and ABBREVIATIONS
(Continued)

RH	Right Hand
RIC	Rockwell International Corporation
RJDA	Reaction Jet Drawer
RMS	Remote Manipulator System
R&PM	Research and Program Management
RPSF	Remote, Processing and Storage Facility(s)
RP-1	Rocket propellant-JP-X based
R/R,R&R	Repair/Replace
RSI	Reusable Surface Insulation
RTOMI	Repetitive Task Operations and Maintenance Instruction
RTS	Remote Tracking System
RTV	Room Temperature Vulcanizing
R&T	Research and Technology
RU	Remote Unit
S	Sulphur
SAFT	Semi-Automatic Flight Line Tester
SAT	Satellite
S&A	Safe and Arm
SB	Space Based
SBS	Space Based System
SBSS	Space Based Space Surveillance (System)
S/C	Spacecraft
SCAPE	Self-Contained Atmospheric Protective Ensemble
SDI	Space Defense Initiative
SDIO	Space Defense Initiative Office/Organization
SDV	Shuttle Derived Vehicle
SiC	Silicon Carbon
SIP	Standard Interface Panel; Strain Isolation Pad
SIT	System Integrated Test
SLSOC	Simplified Launch System Operational Criteria
SM	Support Module
SMA	Shape-Memory Alloy
SMCH	Standard Mission Cable Harness
SME	Shape Memory Effect
SOA	State-of-Art
SOC	Satellite Operations Center
SOPC	Shuttle Operations Planning Center
SOW	Statement of Work
SPACECOM	Space Command
SPADOC	Space Defense Operations Center
SPC	Shuttle Processing Contractor (Lockheed)
SPIDPO	Shuttle Payload Integration and Development Program Office (JSC)
SPDMS	Shuttle Processing Data Management System
SPI	Standard Practice Instructions
SRB, SRBs	Solid Rocket Booster(s)
SRM, SRMs	Solid Rocket Motor(s)
SRSS	Shuttle Range Safety System
SS	Space Station
SSME	Space Shuttle Main Engine(s)
SSMEC	Space Shuttle Main Engine Controller
SSSF	SRB Segment Storage Facility
SSTO	Single Stage to Orbit
ST	Space Telescope
STA,STAS	Space Transportation Architecture (Study)
STC	Satellite Test Center
STE	Systems Test and Evaluation or Special Test Equipment
STS	Space Transportation System; Shuttle Transportation System

ACRONYMS and ABBREVIATIONS
(Continued)

STS II	Space Transportation System II
SV	Space Vehicle
S\W,(SW)	Software
T-III	Titan III
TACAN	Tactical Navigation
TARS	Turnaround and Reconfiguration Simulation
TAV	Transatmospheric Vehicle
TBD	To be Determined/Defined
T&C/O	Test and Checkout
TDAS	Tracking and Data Acquisition Satellite
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TE	Test Equipment
Tempest	Electromagnetic emission suppression for security purposes
TIS	Technology Identification Sheet
TM	Telemetry
TP	Test Point; Test Plan
T-0	Liftoff Time
TOs	Transfer Orbit Stage
TPS	Thermal Protection System; Test Preparation Test
TRAJ	Trajectory
TS	Transportation System
T/S	Test Setup
TSM	Tail Service Mast
T&CN	Telemetry & Communication Network
TTL	Transistor/Transistor Logic
TVC	Thrust Vector Control
UART	Universal Asynchonous Transistor
UDMH	Unsymmetrical Dimethylhydrazine
UDS	Universal Documentation System
UEXCV	Unmanned Expendable Cargo Vehicle
UFRCV	Unmanned Fully Reusable Cargo Vehicle
UFRGB	Unmanned Fully Reusable Ground Based-OTV
UFRSB	Unmanned Fully Reusable Space Based-OTV
UHF	Ultra High Frequency
ULCE	Unified Life Cycle Engineering
ULV	Unmanned Launch Vehicle
UPRCV	Unmanned Partially Reusable Cargo Vehicle(s)
UPRCV(R)	Unmanned Partially Reusable Cargo Vehicle with Return
UPXCV	Unmanned Partially Expendable Cargo Vehicle
UMB	Umbilical
VAB	Vehicle Assembly Building
VAFB	Vandenberg Air Force Base
VC1	Visual Clean 1 (standard)
VC1A	Visual Clean 1A (sensitive)
VC2	Visual Clean 2 (highly sensitive)
VHF	Very High Frequency
VHMS	Vehicle Health Monitoring System
VHSIC	Very High Speed Integrated Circuit
VIB	Vertical Integration Building
VIF	Vertical Integration Facility
VLSI	Very Large Scale Integration
VPF	Vertical Processing Facility

ACRONYMS and ABBREVIATIONS
(Continued)

WAD	Work Authorization Document
WBS	Work Breakdown Structure
WEM	Water Electrolysis Module
WCCS	Window Cavity Conditioning System
WSMC	Western Space and Missile Center
WCS	Waste Conditioning System
WSB	Water Spray Boiler
WTR	Western Test Range
XTKB	Expanded Technology Knowledge Base

1.0 INTRODUCTION

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1.0 INTRODUCTION

BACKGROUND: The Simplified Launch System Operational Criteria (SLSOC) must include elimination of STS-type cost drivers. Incremental improvements of STS technology and methods cannot improve LCC by an order-of-magnitude. Major surgery must be applied to STS-mentality. A radically simplified baseline operations concept must be developed so that proposed designs can be delta'd against simplicity rather than STS-complexity.

The SGOE/T study has evolved, as a sample, a simplistic idealized example which would undoubtedly become more complex with implementation -- nevertheless, it provides a minimum launch system baseline for comparison.

OBJECTIVE: The first objective of the SLSOC is to identify operations that drive operations costs; the second objective is to identify related technology that would reduce operations costs. The third objective is to provide interim release of a reference book for a subsequent series of SLSOC workshops.

APPROACH: The approach is to develop individual operational requisites for: (1) the associated management systems; (2) integration engineering; (3) Avionics and Software; (4) Power; (5) Structures and Materials; (6) Propulsion; and (7) Facilities and Support Equipment.

"SLSOC Interrelated Alternatives" Figure 1.0-1, outlines the unavoidable interrelationships that must be considered between facilities, integrated launch configuration, and the vehicle systems. Figure 1.0-2, "Simplified Launch System Operational Criteria (SLSOC)", lists the essential elements of each design category and names the operations requirements for each element. Backup sheets provide expansion of these requirements (Section 2.0). This expansion includes the associated rationale, sample concepts, identification of technology developments needed, technology references and abstracts. The XTKB (See Volume 1), was used to screen thousands of abstracts to obtain the 300 plus citations pertinent to SLSOC and is included in Volume 5 of this report.

The next section in this document demonstrates feasibility of the operational requirements by developing a radical, but potentially workable, concept which includes an example vehicle and its related ground operations including a headcount and facility analysis.

The final step will be for SLSOC designers to satisfy the operations requirements in a way that will reduce the current operations life cycle costs (STS) by a factor of ten. Keep in mind that past trade studies are no longer valid; technology changes daily and old trades were done with inaccurate estimates of operations costs.

In the final analysis, all designs are compromises. In this document we have outlined the operations cost drivers and have put forth at least one example for each cost driver that, when integrated, would generate an order-of-magnitude cost reduction.

GOALS: All of us have prejudices, based on our individual experiences over the years, as to what will or will not work. Uncontrolled growth, based on those experiences, is a major reason why our current Life Cycle Costs (LCC) have become exorbitant. Vehicle design has been performance oriented and resultant operations methods/techniques have been based on those vehicle designs. Designers have had no previous hard requirement and therefore, little or no incentive to design vehicles based on LCC -- that is, until NOW.

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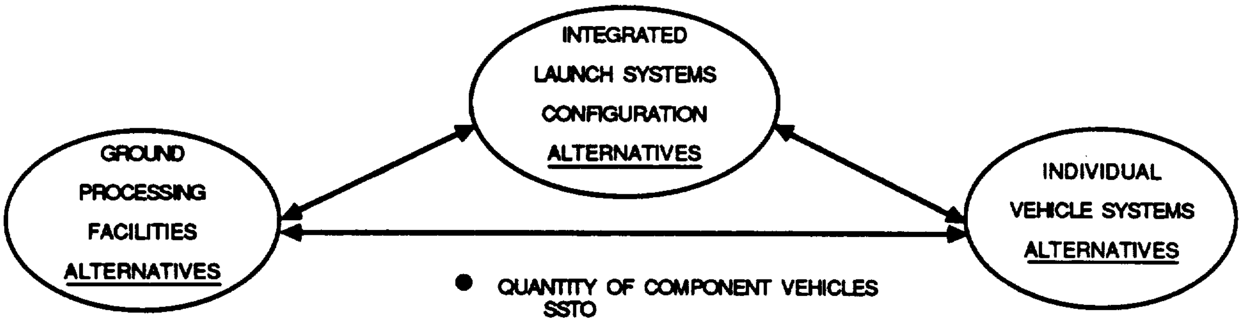
SLSOC Interrelated Alternatives



- VEHICLE PROCESSING MODE
  - VERTICAL
  - HORIZONTAL
  - COMBINATION
- PAYLOAD PROCESSING MODE
  - VERTICAL
  - HORIZONTAL
  - COMBINATION
- PAYLOAD INTEGRATION
  - OPF ONLY
  - VAB ONLY
  - PAD ONLY
  - COMBINATION
- VEHICLE MATE
  - HORIZONTAL
  - VERTICAL
- ERECTION
  - VAB
  - PAD
- VEHICLE ACCESS
  - ALL LOCATIONS
  - OPF ONLY
  - COMBINATION
- TRANSFER TO PAD
  - ML / CT vs DOLLIES
  - BARGE
  - LANDING GEAR
  - ERECTOR / TRANSPORTER
  - RAIL
- PAD SYSTEMS

- QUANTITY OF COMPONENT VEHICLES
  - SSTO
  - 2 - STAGE
  - 3 - STAGE
- COMPONENT VEHICLE MATING
  - STACK
  - PARALLEL
  - COMBINATION
- FUEL
  - SINGLE
  - MULTIPLE
- RECOVERABLE
  - ALL
  - PART
  - NONE
- LANDING
  - HORIZONTAL
  - VERTICAL
  - LAND
  - WATER
- MANNED
  - FLIGHT CREW
  - PASSENGER MODULE
  - ONLY

- PROPELLANTS
  - LOX
  - RP-1
  - LH2
  - CH4
  - C3H8
  - SOLIDS
  - HYPERGOLS
- ON - BOARD POWER
  - FUEL CELLS
  - BATTERIES
  - COMBINATIONS
  - HYDRAULIC SUPPLY
    - APU
    - MPS
- PNEUMATICS
  - PURGE
  - VALVE CONTROL
- TEST - & - C / O
  - MANUAL
  - AUTOMATIC
  - AUTONOMOUS
  - INTEGRATED
- PRESSURIZATION
  - BOTTLES
  - AUTOGENOUS
  - MPS

THE UNAVOIDABLE INTERRELATIONSHIPS OF GROSS VEHICLE CONFIGURATION, VEHICLE SYSTEMS, AND GROUND SUPPORT PROCESSING ARE INDICATED. PRELIMINARY DESIGN MUST ACCOMMODATE EXPERIENCED PERSONNEL FROM ALL THREE TO MINIMIZE LCC

Figure 1.0-1

S G O E/T STUDY
PHASE-2 FINAL
PRESENTATION
by BOEING

SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA (SLSOC)

PRESENTED AT
KSC
APR. 6, 1988

MANAGEMENT & SYSTEM ENGINEERING

- M 1) ● PROCUREMENT
- M 2) ● DESIGN / BUILD TEAMS
- M 3) ● DEMING STYLE MANAGEMENT
- M 4) ● LIFE CYCLE COSTS
- M 5) ● DESIGN TO COST
- M 6) ● UNIFIED LIFE CYCLE ENGINEERING
- M 7) ● RISK MANAGEMENT
- M 8) ● RELIABILITY / OPERABILITY
- M 9) ● MAINTAINABILITY / SUPPORTABILITY
- M 10) ● LOGISTICS SUPPORT
- M 11) ● OPERATIONAL TEST REQUIREMENTS
- M 12) ● QUALITY ASSURANCE
- M 13) ● SAFETY
- M 14) ● SECURITY
- M 15) ● CONNECTIVITY ARCHITECTURE

ELIMINATE

- M 1) O MULTIPLE PRIME CONTRACTORS ON SAME PROGRAM
- M 6) O TIGER TEAMS FOR STATUS (SEE L 1) (Requires 100% Computer Connectivity)
- M 1) O SEPARATE DESIGN CONTRACTORS / VOLUMINOUS INTERFACE CONTROL
- M 12) O LARGE QUALITY INSPECTION TEAMS
- M 10) O CANNIBALIZATION
- M 4) O COST OVERRUNS & UNLIMITED LCC
- M 7) O EXORBITANT COST TO ATTEMPT ZERO RISK REQUIREMENTS

AVIONICS & SOFTWARE

● AUTONOMOUS VEHICLE

- A 1) ● BIT / BITE (ON - BOARD CHECKOUT)
- A 2) ● FAULT TOLERANT AVIONICS SUITE
- A 1) ● VEHICLE HEALTH & STATUS MONITORING SYSTEM
- A 4) ● MINIMAL LAUNCH CONTROL INTERFACE
- ■ A 1) ● RETURNED VEHICLE SELF - TEST FOR REFLIGHT
- A 3) ● AUTONOMOUS G N & C
- A 4) ● OPTICAL / IR / RF LINK ONLY TO GSE

● SOFTWARE

- A 5) ● COMMON "CORE" SOFTWARE FOR C/O, LAUNCH, FLIGHT
- A 5) ● OPERATIONS DATA OVERLAYS (C/O, LAUNCH, MISSION)

ELIMINATE

- A 6) O RELATED GSE
- A 4) O HARDWIRE CONNECTS TO GSE
- E 1) O GROUND POWER REQUIREMENTS

POWER

- E) ● LOW MAINTENANCE ENERGY STORAGE
- E) ● PROPELLANT GRADE FUEL CELLS
- E) ● STATE - OF - ART ENERGY SOURCES
- E) ● SYSTEM SIZED TO PROVIDE ON - BD PWR FOR GROUND OPERATIONS

ELIMINATE

- A 6) O RELATED GSE
- E) O GROUND POWER REQMTS

STRUCTURES & MATERIALS

● IMPROVED STRUCTURE

- S 1) ● SIMPLY CONFIGURED LEAKPROOF TANKS
- ■ S 2) ● STRUCTURAL INTEGRITY VERIFICATION
- ■ S 3) ● INTEGRAL TPS

S 4) ● ORDNANCE

- S 4.1) ● WEAPON DESTRUCT
- S 4.2) ● LASER IGNITION
- ■ S 4.3) ● ACCELERATION / CLEVIS SEPARATION
- S 4) ● NITINOL / E - M DEVICES

ELIMINATE

- S 3) O SEPARABLE TPS
- S 4) O ALL ORDNANCE
- S 4) O PROCESSING SAFETY RESTRICTIONS

PROPULSION

● INTEGRATED PROPULSION SYSTEM

- P 1) ● SIMPLIFIED ROBUST PROPULSION SYSTEM
- P 1.1) ● FULLY THROTTLEABLE ENGINES (MULTI-PHASE)
- P 1.2) ● SOFT ENGINE START
- P 1.3) ● TVC BY DELTA THRUST AND/ OR RCS / OR AERO
- P 1.4) ● ONE OXIDIZER / ONE FUEL

ELIMINATE

- P 2) O SEPARATE OMS AND RCS
- P 3) O HIGH MAINTENANCE TURBOPUMPS
- P 4) O HYDRAULICS
- P 5) O HYPERGOLS
- P 6) O GN_2 / He ON-BOARD PURGES
- P 7) O GN_2 / He PRESSURE SYSTEM
- P 8) O GIMBALLED ENGINES
- ■ P 9) O EXTENSIVE RECOVERY & REFURBISHMENT

FACILITIES & SUPPORT EQUIPMENT

L 1) ● 100% COMPUTER CONNECTIVITY

● AUTOMATION

- L 2) ● ELECTRONIC OMI's
- L 3) ● TEXT AND GRAPHICAL DATA ACQUISITION
- L 4) ● TEST REQUIREMENT VERIFICATION

● STAGE ASSEMBLY

- L 5) ● INITIAL NEAR LAUNCH CENTER
- L 5) ● FINAL AT LAUNCH CENTER

■ L 6) ● HORIZONTAL PROCESSING

- ■ L 7) ● HORIZONTAL TRANSPORT

● PAYLOADS

- L 10) ● ONE AUTONOMOUS CONTAINER

● PAD

- L 8) ● BARREN PAD
- ■ L 9) ● ERECT / MATE STAGES AT PAD
- L 8.1) ● DEEP WATER EXHAUST BUFFER
- L 8) ● LIGHTNING / LIGHTING TOWER
- L 8.2) ● FLY-AWAY CONNECTS ONLY
- L 8) ● PROPELLANT FARM
- ■ L 6) ● PAVED TOW - WAY

● MOBILE EQUIPMENT

- ■ L 6 ● STANDARD AIRCRAFT TUG
- ■ L 6 ● STRAP-ON WHEELED DOLLIES
- ■ L 6 ● MOBILE CRANE

● BUILDINGS

- ■ L 6 ● HORIZONTAL PROCESSING FACILITY

ELIMINATE

O AUTOMATION

- L 1) O ISOLATED DATABASES
- L 2) O PAPERWORK RELATED TO TEST
- L 4) O REQUIREMENTS VERIFICATION
- L 3) O PRINTED TRANSFER OF TEXT / DATA

L 10) O PAYLOAD / VEHICLE INTEGRATION VERIFICATION TESTING

■ L 9) O LIFTING VEHICLES CLEAR OF GROUND

O PAD EQUIPMENT

- L 4) O HARDWIRE CONNECTS
- L 8.4) O ACCESS STRUCTURES
- L 8.3) O SWINGARMS
- L 8) O RETRACTING UMBILICALS
- L 8.5) O T-O HOLD-DOWN
- L 8.6) O DELUGE WATER
- L 8.6) O SOUND SUPPRESSION WATER
- L 8.1) O FLAME TRENCH / DEFLECTOR
- L 8.7) O ECS
- P 6) O He / GN_2 STORAGE
- E) O GROUND POWER
- ■ L 7) O CRAWLER WAY

O MOBILE EQUIPMENT

- ■ L 7) O CRAWLER / TRANSPORTER
- ■ L 7) O MOBILE LAUNCH PLATFORM

O BUILDINGS

- ■ L 6) O VAB
- ■ L 6) O VPF
- ■ L 6) O RPSF

NOTE:

■ THESE ITEMS WERE CONSISTENT WITH THE PRELIMINARY ALS RFP BUT MAY NOT BE APPLICABLE TO CURRENT DESIGN CONCEPTS

Figure 1.0-2

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2.0 SIMPLIFIED LAUNCH OPERATIONAL CRITERIA (SLSOC)

2.1 MANAGEMENT AND SYSTEM ENGINEERING

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SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA
MANAGEMENT & SYSTEM ENGINEERING

M 1) ● PROCUREMENT
M 2) ● DESIGN / BUILD TEAMS
M 3) ● DEMING STYLE MANAGEMENT

M 4) ● LIFE CYCLE COSTS
M 5) ● DESIGN TO COST
M 6) ● UNIFIED LIFE CYCLE ENGINEERING
M 7) ● RISK MANAGEMENT
M 8) ● RELIABILITY / OPERABILITY
M 9) ● MAINTAINABILITY / SUPPORTABILITY
M 10) ● LOGISTICS SUPPORT
M 11) ● OPERATIONAL TEST REQUIREMENTS
M 12) ● QUALITY ASSURANCE
M 13) ● SAFETY
M 14) ● SECURITY
M 15) ● CONNECTIVITY ARCHITECTURE

ELIMINATE

M 1) ○ MULTIPLE PRIME CONTRACTORS ON SAME PROGRAM
M 6) ○ TIGER TEAMS FOR STATUS (SEE L 1) (Requires 100% Computer Connectivity)
M 1) ○ SEPARATE DESIGN CONTRACTORS / VOLUMINOUS INTERFACE CONTROL
M 12) ○ LARGE QUALITY INSPECTION TEAMS
M 10) ○ CANNIBALIZATION
M 4) ○ COST OVERRUNS & UNLIMITED LCC
M 7) ○ EXORBITANT COST TO ATTEMPT ZERO RISK REQUIREMENTS

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No: M1 **Title:** Procurement

Operations Requirement:

Government procurement must utilize a contracting mode that establishes prime contractors with sufficient system integration authority to define system (hardware and software) configuration requirements. This will enable cost-effective management for the total system architecture (including hardware acceptance and sub-contractor control).

Rationale:

Contracts that specify GFE, such as engines, and dictate detailed specifications rather than end product performance severely limit a prime contractor's ability to achieve the optimum design or manage the job in a cost effective manner. Most detail hardware specifications limit the contractor's capability to be innovative and cost effective.

Sample Concept:

Program level specifications should be developed only for the top level of end product performance and include profit incentives.

Production contracts for systems / components should be placed under control of the prime contractor.

For Example: The lunar orbiter program was a highly successful performance incentive program that operated under this concept.

Technology References:

SGOE/T Study Report, Volume 3, Part 2, 4 May 88.

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No: M2 **Title**: Design/Build Teams

Operations Requirement:

Beginning with the conceptual definition through the design phase, integrate the experience and knowledge of specialists in all areas, including manufacturing, procurement, ground operations, etc.

Rationale:

As a result of compartmentalized organization responsibilities, past vehicle designs have not fully utilized and integrated the knowledge and experience of specialists in all functional organizations.

The past sequence of hardware development, whereby the hardware designer completes his design (without input from manufacturing, purchasing, operations, etc.) and "throws it over the fence", for the other organizations to do the best they can in producing and operating the hardware in a cost-effective way, has led to life cycle cost an order-of-magnitude higher than necessary.

Sample Concept:

Management must adopt design/build team concepts. This will provide an adequate flow of experience and coordination from operational elements to engineering design during the definition and development stage.

Individual program requirements should determine its organizational structure -- not vice-versa.

Technology Requirement:

Advanced teamwork.

Technology References:

SGOE/T Study Phase 2 Final Report, Volume 3, Part 2, dated 5/4/88.

SGOE/T Study Phase 1 Final Report, Volume 1, pp.14-16, dated 5/4/87.

No: M3 **Title**: Deming Style Management

Operations Requirement:

Traditional compartmented management style must be replaced with Deming-type, team-style management with integrated quality.

Rationale:

In maturing over the past twenty-five years, aerospace management, both in and out of government, have succumbed to bureaucratic disease whereby the first consideration of any management or technical problem is how it will affect the "status quo". If the effect is negative in any way, the answers are often skewed preventing top management from making cost effective decisions. Top management also suffers from biased decisions made to accommodate their "status quo".

Sample Concept:

Computerized databases can eliminate need for many middle managers who now only gather and provide information for top management decisions. This will allow top managers who know how to effectively use computer tools to obtain data that is unfiltered and unbiased by middle management protecting their turf.

Management culture must change to a more participative management style (a la Deming) without wasteful department barriers. This must take place both in NASA and contractor ranks.

With a high percentage of managers in NASA and contractors approaching retirement, there is an unusual opportunity to accomplish the change. Care must be taken not to replace these retiring managers with their look-alike proteges or nothing will be gained. Selection of new managers should be based on their ability to make imaginative use of the latest management technology and who are not ingrained with parochial viewpoints.

The individual program objectives should determine the organization requirement -- not vice-versa.

Technology Requirement:

A total culture change in managerial techniques. Brain restructuring.

Technology References:

"Managing Quality" Handbook, Boeing Aerospace Co., September '85

"The Deming Route to Quality and Productivity", W.W. Scherkenbach 1986.

SGOE/T Study Report, "SOCH Appendices", Draft dated 9/8/87.

No.: M4 **Title:** Life Cycle Costs (LCC)

Operations Requirement:

Operations efficiency must be considered during concept development and design.

Rationale:

Operations requirements have been disregarded in the past because they are brought up too late in the design cycle to be implemented in a cost-effective manner.

FOR EXAMPLE (FY-85 STS OPERATIONS COSTS FOR 8 FLIGHTS):

SRB	$464.2M	FLIGHT OPS	$345.3M
ET	415.8M	ORBITER HDWRE	162.6M
LAUNCH OPS	347.5M	CREW EQUIP.	36.3M
PROPELLANTS	30.3M	SSME	51.6M
GSE	24.1M	CONTRACT ADMIN.	17.1M

SUBTOTAL $1894.8M

PLUS NETWORK SUPPORT $ 20.4M
R & PM 274.2M

FY-85 TOTAL COST $2189.4M (in '85 dollars for 8 flights)
or $ 273.5M per flight

Minimizing upfront program costs multiplies Life Cycle Cost.

Sample Concept:

Do not sacrifice operational efficiency for vehicle performance. Build a truck - not a Ferrari.

Prepare thorough and realistic life cycle cost analysis for Congress. Emphasize Life Cycle Cost - not start-up costs.

Implement tools listed below.

Technology Requirement:

No new technology required, only further development and implementation of the proper concepts and tools:

DEMING MANAGEMENT AND QUALITY TECHNIQUE
ULCE (Unified Life Cycle Engineering)
DESIGN/BUILD TEAMS
MAINTAINABILITY
SUPPORTABILITY
DESIGN-TO-COST
MANDATORY MTBF/MTTR

Technology References:

NASA/RECON (See Volume 5): 86X75319, 86N28011, 86A42678, 86A42618, 86A21872, 86A10929, 85A45150, 85N30966, 85A42678, 84X78919, 84N31062, 84N26962, 84N24495, 84N23330, 84A15212, 83A43748, 84A30608, 83A49578 83A48334, 82A14787, 81N11907, 81A30295

No.: M5 **Title:** Design to Cost

Operational Requirement:

Assure that adequate Design-to-Cost budget is allocated to operational considerations such as maintainability / supportability.

Rationale:

The history of previous programs is fraught with Life Cycle Cost extravagances casued by inadequate front-end budget considerations for operations related design.

Technology References:

NASA/RECON (See Volume 5): 84N19129, 81N29023, 81N11907

DoD directives 5000.1 and 5000.28.

See also M4 (Life Cycle Costs).

No: M6 **Title**: ULCE (Unified Life Cycle Engineering)

Operations Requirement:

Use Unified Life Cycle Engineering (ULCE). This is a design engineering environment in which computer-aided design technology is used to continually assess and improve the quality of a product during the active design phases as well as throughout its entire life cycle. This is accomplished by integrating and optimizing design attributes for producibility and supportability with design attributes for performance, operability, cost, and schedule.

Rationale:

No integrated methodology or discipline has been used to provide advantageous computerized integration of producibility and supportability with performance, cost and schedule.

Sample Concept:

Implement Unified Life Cycle Engineering (ULCE) system to provide birth-to-death unified design environment.

USAF Project Forecast II's ULCE (PT-32) provides the environment for all design attributes (e.g. Performance, producibility, support, quality, cost, schedule, etc.) to be appropriately addressed during the design process taking maximum advantage of computer techniques. Provide for computerized approval/concurrence control of requirements, procedures, and anomaly close-outs as part of ULCE; also provide for risk management, configuration control, mission/range support, flight readiness reviews, resolution of in-flight anomalies. etc.

Technology Requirement:

Continued development of ULCE.

Technology References:

SGOE/T Study Report, "SOCH Appendices", Draft dated 9/8/87.

No.: M7 **Title:** Risk Management

Operational Requirement:

The unmanned ALS program requires compliance with a non-emotional, well-engineered risk management program.

Rationale:

Trying to provide a "zero-risk" launch program is like dividing cost by zero.

The emotionalism and overreaction to the loss of Challenger, has impacted the STS program far more than a logical risk management program. In addition to the two plus years of manifests that were lost, future vehicle processing time has tripled from the pre-Challenger goal.

Launch readiness decisions must be made by technically qualified managers bases on a disciplined test and qualification requirements compliance database.

Sample Concept:

Effective use of the Design/Build Team concept which utilizes the knowledge and experience of all disciplines should contribute significantly to an effective risk management program.

Use of the Unified Life Cycle Engineering (ULCE) concept will provide the tools to follow through on the risk management program.

Vehicle systems that are fault tolerant and closely monitor health of avionics, mechanical systems and structures.

Technology Requirement:

Stringent use of the Design/Build Team concept.

Further development of the ULCE modules.

Fault tolerant avionics

Comprehensive vehicle health monitoring system to include avionics, mechanical systems and structures.

Technology References:

NASA/RECON (See Volume 5): 84N19124

See also M2, M6, A1, A2, S2.

No.: M8 **Title:** Reliability / Operability

Operational Requirement:

To provide a vehicle with adequate system availability, resiliency, and schedule dependability to eliminate schedule impact and resulting process cost (i.e. manpower and overtime).

Rationale:

The processing history at ETR and KSC of both expendable and recoverable vehicles support this requirement. Included below are typical items which surfaced during Phase 1 of this Study.

Sample Concept:

1. Launch vehicles must be designed with very large performance margins and system redundancy:

   . To allow operation well within design margins.

   . To ensure mission completion despite hardware failure.

   . To require less pre-launch testing.

2. Systems and components must be simplified and ruggedized to reduce failure modes.

3. Performance margins must be increased and more extensive qualification testing performed to increase MTBF.

4. Designs must include status monitoring features so that system health can be easily and quickly determined.

5. Performance must be completely mapped as a function of time-in-service so that maintenance and replacement can be planned to minimize operational impacts.

6. STS experience indicates need for a continuous ground hot fire test program with multiple engines that demonstrate operational time far in excess of fleet leader.

7. Provide drainage at lowest point in hollow structures to prevent corrosion or freezing stress.

Technology Requirement:

None

Technology References:

NASA/RECON (See Volume 5): 86X70507, 86N28011, 86N24579, 86N21425, 86N20054, 86A22393, 86A22391, 85X72180, 84N23813, 84A15215, 84A15212

SGOE/T Final Report, Phase 1, 4 May 1987

No.: M9 **Title:** Maintainability/Supportability

Operational Requirement:

Maintainability / supportability must get high priority in Design / Build Team representation.

Rationale:

Analysis of STS cost drivers in Phase 1 of this study includes, for example, documentation of some 226 maintainability issues (problems) and 104 accessibility issues. Most of these would not have occurred if adequate consideration / priority had been assigned before the design was cast in concrete.

Sample Concept:

Strong representation of maintainability and operations disciplines or Design / Build Teams.

Technology Requirement:

None.

Technology References:

NASA/RECON (See Volume 5): 86N24579, 86N20054, 86A32095, 86A22391, 86A22380, 85X72180, 85N16743, 84N22528

No.: M10 **Title**: Logistics Support

Operational Requirement:

Provide adequate spares provisioning from the beginning.

Rationale:

Spare parts provisioning is yet another illustration that the Shuttle Program was not prepared for an operational schedule. The conscious decision was made to postpone spare parts procurements in favor of budget items of perceived higher priority. The policy proved to be shortsighted and has led to the inefficiencies of cannibalization to support the flight rate.

From the Challenger Presidential Commission Report, "The logistics support for 51-L ground processing was inadequate, since it created a need to remove parts from other orbiters to continue 51-L operations. For 51-L, 45 out of approximately 300 required parts were cannibalized. These parts ranged from bolts to an OMS TVC actuator and a fuel cell. The significance to operations of cannibalization is that it creates (1) significantly increased efforts to accomplish the same work due to multiple installation and retest requirements, (2) schedule disruption due to added work and normally later part availability, and (3) orbiter damage potential due to increased physical activity in the vehicles. These efforts make cannibalization operationally unacceptable."

Sample Concept:

Accept the necessary up-front costs of adequate spares provisioning in order to reduce Life Cycle Costs with more efficient operations.

Technology Requirement:

None

Technology References:

NASA/RECON (See Volume 5): 87A27619, 86A30550, 85N11996, 84N26962

No.: M11 **Title:** Operational Test Requirements

Operational Requirement:

Valid operational test requirements should be defined by the Design/Build Team (see M2) and integrated into VHMS (Vehicle Health Monitoring System) where possible.

Rationale:

Current and past LV programs, at both ETR and KSC, test and retest at the instigation of individual design, test, and technical management organizations (Contractor, NASA, and Aerospace). All of these practice CYA to extreme levels. Further, "once a test, always a test", with little or no effort made to remove test requirements which can no longer be justified. Many of these tests are the result of inadequate incorporation of operations experience in the design.

Even where the design includes self-test capability, old habits die hard. For example, on IUS, pre-deployment checkout utilizes a VHMS and verifies IUS readiness for deployment in approximately two minutes. Equivalent ground testing requires extensive manpower and GSE which manually sequences each test step, with serial manpower-intensive data analysis. Each time the IUS is moved, it is retested in this manner resulting in many additional weeks of test time.

Sample Concept:

Implement VHMS concept to fullest capability and not allow its capability to be duplicated at the test site with GSE and manpower in a make-work scenario.

Eliminate test/retest requirements imposed at the test site by the subjective confidence level of test engineers and/or technical management personnel. Unnecessary requirements are often imposed by personnel with no responsibilty for cost or schedule.

Technology Requirement:

VHMS

Technology References:

SGOE/T Study, Phase 1, Final Report, 4 May 1987.

No.: M12 **Title:** Quality Assurance

Operational Requirement:

A modern QA program that virtually eliminates the requirement for a large force of Quality inspectors with its inherent inefficiencies impacting processing times and costs.

Rationale:

Quality Assurance places emphasis on inspection. As a result of the Challenger loss and the Presidential Commission Report, program management has amplified this problem by increased manpower and efforts to inspect quality into the product. American industry, led by Japan's implementation of Deming's methods, is beginning to understand that inspection is not only costly, but also ineffective.

Sample Concept:

New systems design should place emphasis on computerized, self-check verification for electrical systems and require minimal inspection for mechanical and structural systems.

Management and workers must be be trained and led into a total quality program (a la Deming - see SGOE/T Final Phase 2, Volume 3, Part 2, SOCH Reference Information, Section 6.2). The Deming approach is not to automate quality verification, but instead to build quality into the product and promote quality workmanship thus eliminating the need for constant inspection. This would require a major change in culture as well as MIL-standards but needs to be done.

Technology Requirement:

Management reset and implementation.

Technology References:

DIALOG REFERENCE: 1934413

Ford Motor Company, Product Quality Office, Dr. Deming's Concepts, Dec. 1981.

Ron Cristofono Workshop Series, DEMING's FOURTEEN OBLIGATIONS OF MANAGEMENT

Scherkenbach, William W., THE DEMING ROUTE TO QUALITY AND PRODUCTIVITY

SGOE/T Study, Phase 2 Final Report, Volume 3, 4 May 1988

No.: M13 **Title:** Safety

Operations Requirement:

Special safety requirements, particularly for ordnance and propellant related items, must be reduced to a bare minimum and preferably eliminated where possible.

Rationale:

Hazardous operations and conditions in the vehicle preparation area greatly affect operations times and increase costs. During such times, technicians are prevented from doing useful work on the vehicle, and only one task can proceed at any one time. To minimize these delays, ordnance operations must be absolutely minimized and preferably eliminated from the processing flow.

Related KSC Schedule History:

1. The 160-hour schedule had 8 hours for ordnance installation at the Orbiter Processing Facility (OPF).

2. Currently 112 hours of processing time is spent in ordnance operations in the following areas:

   OPF..8 hours
   External Tank (E/T) Checkout Cell..............22 hours
   Vehicle Assembly Building (VAB)................44 hours
   PAD..36 hours
   (20 hours requires complete pad clear)

   Total 112 hours (Total on-line serial time 44 hours)

   This schedule is primarily taken from the as-run of 51-L, then modified to simulate a typical STS flow.

   The eight hours of scheduled ordnance work in the OPF is considered serial time since area clearing is required and restrictions are placed on other activities.

   The 66 hours in the VAB (including the E/T checkout cell is parallel work since it is primarily done while the orbiter is in the OPF. It does restrict some other work in the VAB.

   The 36 hours at the pad is the most detrimental to the schedule. At least 20 hours requires clearing the whole pad and it would be hard to calculate how many man-hours of other work are lost.

Sample Concept:

Management must assure that program requirements and RFP's reflect this requirement to minimize the impact of safety requirements through appropriate design, requirements and procedures. Also, the management of design, safety, quality, and operations personnel must assure that requirements and procedures are not redundant for CYA purposes only.

Technology Requirement:

See S4.

Technology References:
NASA/RECON (See Volume 5): 85A13163

No.: M14 **Title:** Security

Operational Requirement:

Security requirements which impact costs (most do) should be minimal and realistic.

Rationale:

Operational costs for past and current programs have been significantly impacted by security requirements. Cost impact data was not available or considered. This cost impact includes security control and accountability of paperwork; controlled access areas; screenrooms; TEMPEST equipment; separate software; etc.

Sample Concept:

Impact (of security requirements) should be defined by the Design/Build team and fed back to Program management for reevaluation of security requirements on Design-to-Cost. In other words, don't run open loop on the cost implication of security requirements.

Technology Requirement:

None.

Technology References:

None.

No: M15 **Title**: Connectivity Architectures

Operations Requirement:

Conform to computer interface standards to allow complete connectivity (both text and graphics) between organizations including Design, Manufacturing, Logistics, Procurement, Operations, etc.

Rationale:

Current methods of information flow is inadequate, not time synchronized (much less in real time), and error prone.

Connectivity architecture is rapidly becoming available which allows ready interchange of data among different computer operating systems and databases.

Significant cost reduction in LCC can be made by contractual requirement to utilize industry / government standards shown on the next two charts.

Technology Requirement:

DoD Internet Architecture.
MIL-STD-1840A.

Technology References:

Final Report SGOE/T Study, Phase 2, Volume 3, Part 2 (ULCE Secton 2.1).

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2.2 AVIONICS AND SOFTWARE

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SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA AVIONICS & SOFTWARE

- AUTONOMOUS VEHICLE
  - A 1) ● BIT / BITE (ON - BOARD CHECKOUT)
  - A 2) ● FAULT TOLERANT AVIONICS SUITE
  - A 1) ● VEHICLE HEALTH & STATUS MONITORING SYSTEM
  - A 4) ● MINIMAL LAUNCH CONTROL INTERFACE
  - ▭ A 1) ● RETURNED VEHICLE SELF - TEST FOR REFLIGHT
  - A 3) ● AUTONOMOUS G N & C
  - A 4) ● OPTICAL / IR / RF LINK ONLY TO GSE
- SOFTWARE
  - A 5) ● COMMON "CORE" SOFTWARE FOR C / O, LAUNCH, FLIGHT
  - A 5) ● OPERATIONS DATA OVERLAYS (C / O, LAUNCH, MISSION)

ELIMINATE

- A 6) ○ RELATED GSE
- A 4) ○ HARDWIRE CONNECTS TO GSE
- E 1) ○ GROUND POWER REQUIREMENTS

NOTE: ▭
These items were consistent with the preliminary ALS RFP but may not be applicable to current design concepts

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No.: A1 **Title:** BIT/BITE (On-Board Checkout)

Operations Requirement:

Current configurations require extensive use of GSE to support vehicle checkout. Future systems should incorporate onboard checkout and minimize (preferably eliminate) GSE.

Vehicles should have sufficient self-test capability to verify flight readiness or isolate problem to LRU.

Rationale:

Current configurations require complex GSE hookups to support system test and operational verification. The configuration verification, required for test hookup and calibration, defeats efficient operations.

To accomplish order-of-magnitude cost reduction, we must achieve 160-Hr or better turnaround time for recoverable stages. (160-Hrs was the original STS Turnaround goal whose actuals have grown an order-of-magnitude). In addition to turnaround times exceeding 1500 hours, aging recoverable vehicles will impose requirements for structural inspections which will require extensive time periods offline. ELV's must have comparable processing times.

Sample Concept:

After a firm set of test requirements has been defined early in the design phase, the associated hardware/software required to support on-board testing must be incorporated in each subsystem. It is important to maintain subsystem self-test autonomy.

BIT identifies and records anomalies during flight. After landing, BIT/BITE isolates problem to LRU level. After replacement, BIT/BITE retests and verifies flight readiness. Ideally, recoverable vehicles would include sensors for complete structural integrity to avoid extensive downtimes.

Technology Requirement:

Further development of Vehicle Health Monitoring System (VHMS) with BIT/BITE to meet specific requirements. Development of structural sensors including corrosion.

Technology References:
NASA/RECON (See Volume 5):
87N10079, 87A33872, 87A32118, 86N20489, 86A32796, 86A31260,
86A40591, 86A23765, 85X77042, 85X70467, 85N20697, 85N16753,
85N16897, 85N16898, 85N16900, 85N11594, 85A13194, 85A45082,
85A24795, 85A28633, 85N34596, 85A45975, 85A45398, 85A26804,
85N22528, 84X76865, 84X74856, 84X71619, 84N14754, 84N26573
84N34500, 84A46661, 83A49578, 83A45473

No.: A2 **Title:** Fault Tolerant Avionics Suite

Operations Requirement:

Avionics systems must provide for higher reliability by providing levels of fault tolerance in support of manrated system availability.

Rationale:

To support onboard checkout and mission success the entire avionics suite must be designed to provide that level of fault tolerance required to assure that the system is available when required. This is best accomplished by assuring the robustness of all mission critical systems, and providing fault tolerance where it is required.

Sample Concept:

Future systems must be designed such that systems in general can be dynamically configured to provide for more than one function. Should an allocated processor or sub-system fail, another processor with a lesser priority function should be assigned to reconfigure and perform the function of the failed processor. This forces a high degree of commonality, and distributed processing. Integrated Fault Tolerant Avionics Suite (IFTAS) is an example of this technique.

Technology Requirement:

Distributed processing, layered architectures, commonality. IFTAS development.

Technology References:

NASA/RECON (See Volume 5):
86X10264, 86X10263, 86N20475, 86N20472, 86N20402, 86A47511, 86A47442, 86A37043, 86A33194, 86A28062, 86A11452, 85X10244, 85N30643, 85N23337, 85N16896, 85N16752, 85N11610, 85N11590, 85N10711, 85A44565, 85A43489, 85A34179, 85A25108, 85A24795, 85A17876, 85A17344, 84K10537, 84A43946, 84A41699, 84A26771, 84A26768, 84A10052, 84A10001, 83N36337, 83A22825, 83N13819, 82A14714, 82A13490

See also E, Section 2.3, Power

No: A3 **Title**: Autonomous GN&C

Operations Requirement:

Eliminate vehicle dependence on GN&C GSE for test and checkout.

Rationale:

Onboard BIT/BITE and Vehicle Health Monitoring System (VHMS) for GN&C can eliminate/simplify/speed-up ground operations.

Sample Concept:

Boeing 757/767 or advanced military aircraft computerized electronics providing self-test and fault identification with fault-tolerant computers. Ability to replace circuit boards without system shutdown. Easy accessibility. See A1, A2.

Technology Requirement:

Further development of BIT/BITE and VHMS.

Technology References:

NASA/RECON (See Volume 5):
87N16551, 87N11735, 87A33249, 87A32117, 87A19603, 86X75348, 86K10299, 86A28490, 85X74761, 85X73876, 85N22229, 85A45971, 85A41019, 85A39562, 85A24795, 84X77582, 84X72233, 84X10357, 84N72750, 84N24603, 84N12237, 84K10744, 84K10153, 84A40143, 84A43401, 84A29544, 84A29543, 84A26701, 84A16526, 84A11999, 83A11175

No: A4 **Title**: No Hardwire to Vehicle; Minimal Launch Control Interface; No Ground Power

Operations Requirement:

Minimize hardwire connections to vehicle to simplify vehicle erection and pad connection sequence. Also, drastically reduce quantity of control and data functions from LCC to pad. Eliminate requirement for ground power.

Rationale:

All systems must be dramatically reduced or simplified to achieve required cost reduction. O&M of vehicle hard connects is costly and labor intensive.

Sample Concept:

Vehicle electrical power is self-contained via high density power cells. Essential ground control functions are relayed to the vehicle via RF, infrared, or equivalent non-hard-connect and related GSE to vehicle. Vehicle connects limited to propellants, holddown mechanism, and electrical ground.

Technology Requirement:

Remote RF and infrared control techniques are in existence. No technology breakthrough required except development of high-density energy cells (see E).

Technology References:

NASA/RECON (See Volume 5): 86A15396, 85A10576, 84X74058, 84X73435, 84K11473, 82A28585, 84A26450, 82N76663, 82N12314

See also E.

No.: A5 **Title:** Software Commonality

Operational Requirement:

The vehicle should utilize the same software for ground operations test and integration as for flight.

Rationale:

Current STS ground operations is accomplished with several different programs depending on the stage of testing. This results in many hours of wasted time in reloading the main computer memory. For example the final prelaunch load requires 14 clock-hours to accomplish.

Sample Concept:

The Avionics should be designed as a distributed system with one or more high speed buses providing communications between subsystems as required.

Each subsystem should have the capability of autonomous ground operations by commanding the system into standalone mode. In this mode all required external stimuli would be simulated by the subsystem in sufficient manner to verify it's proper operation. This would allow each subsystem to be tested independently of the operational state of the other systems. When all ground testing and vehicle integration is complete each subsystem would be commanded to the flight mode without additional computer reloading.

Technology Requirement:

Distributed architecture.

Technology References:

IUS software.

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2.3 POWER

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SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA
POWER

E) ● LOW MAINTENANCE
ENERGY STORAGE

E) ● PROPELLANT GRADE
FUEL CELLS

E) ● STATE - OF - ART
ENERGY SOURCES

E) ● SYSTEM SIZED TO
PROVIDE ON - BD
PWR FOR GROUND
OPERATIONS

ELIMINATE

A 6) ○ RELATED GSE
E) ○ GROUND POWER REQMTS

PAGE 38 INTENTIONALLY BLANK

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No.: E **Title:** Eliminate Requirement for Ground Power

Operational Requirement:

Vehicle systems that operate off vehicle power without requirement for ground power connection at any time during checkout or launch operations.

Onboard power source capable of providing sufficient power for ground O&M, T&C/O, and launch operations without connection to facilities or GSE.

Provide a low maintenance state-of-the-art energy storage source. If energy source is H_2-O_2 fuel cell, then it should use propellant-grade H_2 and O_2.

Rationale:

The requirement for ground power not only requires complex GSE, but also requires umbilical connections and, in some cases, towers and swingarms. Each of these require extensive checkout time and personnel (engineers, technicians, mechanics, inspectors, and clerks) in support.

Requirement for special high-grade H_2 and O_2 for fuel cells creates additional logistics, GSE, personnel, and timeline needs.

Sample Concept:

High density energy storage systems, such as regenerative fuel cells or sodium/sulphur batteries to provide adequate on-board power for ground O&M, T&C/O. Fuel cells should be capable of using propellant-grade H_2 and O_2.

Technology Requirement:

Accelerated development of energy storage systems with emphasis on fuel cells and consideration of sodium/sulphur batteries.

Technology References:

NASA/RECON (See Volume 5):
87X70518, 87N22801, 87N19811, 87N19809, 87N17397, 87N16453, 87N14860, 87N12998, 87A33793, 87A33790, 87A33778, 87A33787, 87A15901, 87A14170, 86X73564, 86X73563, 86X72121, 86X71138, 86X70734, 86N28331, 86N28329, 86N27586, 86N23047, 86N17886, 86N16734, 86N16495, 86N14764, 86C12215, 86B10483, 86B10277, 86A37201, 86A36369, 86A24845, 85X76813, 85X72247, 85N71096, 85N33588, 85N16292, 85N31372, 85N13880, 85N13850, 85A45422, 85A33144, 85A26700, 85A26501, 85A12599, 84X75772, 84N31535, 84N12246, 84N10493, 84A30956, 84A30107, 84A30103, 83N14683, 81N22305, 81K10462, 80A20128, 75N24837

PAGE 40 INTENTIONALLY BLANK

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2.4 STRUCTURES & MATERIALS

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SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA
STRUCTURES & MATERIALS

● IMPROVED STRUCTURE

S 1) ● SIMPLY CONFIGURED LEAKPROOF TANKS

▭ S 2) ● STRUCTURAL INTEGRITY VERIFICATION

▭ S 3) ● INTEGRAL TPS

S 4) ● ORDNANCE

S 4.1) ● WEAPON DESTRUCT

S 4.2) ● LASER IGNITION

▭ S 4.3) ● ACCELERATION / CLEVIS SEPARATION

S 4) ● NITINOL / E - M DEVICES

ELIMINATE

S 3) ○ SEPARABLE TPS

S 4) ○ ALL ORDNANCE

S 4) ○ PROCESSING SAFETY RESTRICTIONS

NOTE: ▭

These items were consistent with the preliminary ALS RFP but may not be applicable to current design concepts.

PAGE 44 INTENTIONALLY BLANK

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No: S1 **Title:** High Strength Lightweight Cryo Tanks

Operations Requirement:

Develop cryo tank materials and designs providing greater leak-proof

Rationale:

Contemporary tankage and plumbing are leak sensitive and require constant ground operations vigilance. Any configuration simplification has positive consequences on ground support operations.

Sample Concept:

An integral tank containing concentric fuel and oxidizer tanks, (fuel and oxidizer must be thermally compatible), eliminating intertank structure and throughtank plumbing.

Propane and methane are cryogenic fuels that possess potential for common bulkhead concentric tanks. The least expensive propane for instance is well suited for this application because its normal freezing point of -305.8° F allows it to remain liquid at the normal boiling point of oxygen (-297.4° F). Another potential benefit of this concept is the densification by thermal conduction to the oxygen during propellant loading.

Technology Requirement:

1. Research in lightweight, internal insulation, easily applied and reusable without maintenance.

2. Development of innovative alloys retaining higher strength characteristics at cryo temperatures.

3. Development of an integral tank configuration with concentric fuel and oxidizer tanks; made possible by cryo-compatible propellants, i.e., LOX and methane or propane where cryo temperatures and/or fuel freezing point are compatible.

Technology References:
NASA/RECON (See Volume 5):
87A33190, 87A13055, 87A13051, 87A13011, 87A11843, 86X75033, 86X74233, 86X73534, 86X10270, 86X10066, 86X10045, 86N22593, 86N13349, 86C12705, 86C00011, 86A40487, 86A36854, 86A36335, 86A31475, 86A31465, 85X74649, 85X10084, 85X10074, 85A46526, 85A45739, 85A43126, 85A41005, 85A39283, 85A37401, 85A37376, 85A35389, 85A27119, 84X73372, 84A34010, 84A32676, 84A28232, 83X72974, 83X72199, 83A37861, 83A33961, 82X73554, 82X71731, 82A47042, 82A38699, 82A24804, 82A23752, 80N30494

No.: S2 **Title:** Structural Integrity Verification

Operational Requirement:

Provide on-board structural verification for recoverable vehicles.

Rationale:

To avoid extensive recoverable vehicle downtimes which severely impact manifest capability. This downtime causes drastic increase in life cycle costs because of reduced flight rate.

Sample Concept:

Recoverable structures designed and manufactured with adequate built-in strain gauges, corrosion sensors, and BIT to provide adequate warning of structure deterioration.

Technology Requirement:

Determination of sensor requirements for structural integrity.

Development of required sensors to detect corrosion, etc.

Technology References:

NASA/RECON (See Volume 5): 87K10697, 85A47011

No: S3 **Title**: Integral TPS

Operations Requirement:

Eliminate time consuming critical inspection and test of orbiter-type TPS.

Rationale:

Orbiter tile has structural characteristics akin to high-density styrofoam, i.e., it's brittle and delicate. Strength of the bond to vehicle substrate is critical and very difficult to ascertain. Repair/test/validation of TPS is very time consuming, requires expensive GSE and high-tech test equipment, and multiple eyes to observe/verify procedures.

Sample Concept:

Provide simplified, skin-integral, large panel, "old technology" TPS, i.e., temperature resistant pyrolytic graphite, metals and composites as proposed for earlier STS concepts. Reexamine and redefine reentry mode to multi-skip, once-around reentry a la Sanger, and reexamine cross-range requirements impact on TPS configuration.

Technology Requirement:

Development only. Previous studies/designs utilized much less sensitive TPS.

Technology References:

NASA/RECON (See Volume 5):
86X10037, 86A18037, 86A15201, 85X10346, 85N12085, 85A38450, 85A28801, 85A17092, 84X74531, 84X10382, 84X10381, 84X10379, 84X10376, 84X10375, 84X10374, 84X10372, 84X10371, 84X10366, 84X10356, 84N32505, 84N24709, 84A47046, 84A42651, 84A41928, 84A37496, 84A37494, 84A37493, 82A31896, 82N23262

No: S4 **Title**: No Ordnance

Operations Requirement:

Eliminate all ordnance devices.

Rationale:

Eliminate all ordnance devices or provide ordnance which is inherently safe for handling purposes. Eliminate or drastically reduce "area clear" for ordnance.

Sample Concept:

Eliminate explosive ignition devices: replace pyrotechnics with lasers. (See S4.2).

Explosive release and separation devices: replace with electromechanical and Nitinol initiated devices. (See S4.3)

Explosive range safety devices: eliminate by using military weapon systems to destroy errant vehicles. Use vehicle-borne beacon to assure identification and assist weapon. (See S4.1).

Technology Requirement:

Development only.

Technology References:

NASA/RECON (See Volume 5):
86X70834, 86N27356, 86A23512, 85N13959, 85A47011, 84A42759, 82N72580, 82N19033, 80X73875

No: S4.1 **Title:** Independent Weapon Destruct

Operations Requirement:

Provide ground-based anti-missile-type battery of circa 1995 weapon systems to provide near-range vehicle destruct. Eliminate extensive non-productive manhours for "area clear" during range safety ordnance installation. Minimize "safety army" and procedures that accommodate contemporary systems and methods.

Rationale:

Elimination of vehicle range safety ordnance and associated non-productive manhours and operational cost is highly desirable. Consider current range safety regulations negotiable.

Sample Concept:

Delete the extensive vehicle/ground remote destruct system. If an unmanned vehicle goes awry during the first minutes of launch (or close to launch site) use ground based anti-missile weapons to provide range destruct. Use beacon on-board space vehicle to assist in identification and guidance. (See S4)

Technology Requirement:

None. Use military antimissile system of circa 1995 vintage .

Technology References:

N/A

No.: S4.2 **Title:** Laser Ignition

Operational Requirement:

Eliminate pyrotechnic type ordnance where possible; At least, provide system with less stringent safety requirements.

Rationale:

There are four types of ordnance devices currently used on STS: ignition, release, separation, and range safety. The special handling safety, area clear, and training requirements make this a major cost area in ground processing.

Sample Concept:

A laser ordnance initiation system provides the capability to reliably control ordnance functions on launch vehicles. Examples of ordnance events which can be controlled by a laser system include motor ignition, stage separation, thermal battery activation, shroud removal, destruct, etc. There are significant improvements in safety, weight, cost, and processing time offered by laser systems over conventional electro-explosive ordnance initiation. The additional capability for safe, positive on-board system interrogation and test can provide an assurance of launch vehicle readiness never before attained with traditional ordnance systems.

See also, S4.

Technology Requirement:

Continued development of laser-initiated ordnance for specific ALS-related requirements.

Technology References:

Vendor data (Ensign-Bickford Co., Aerospace Division, Simsbury, Connecticut).

No: S4.3 **Title:** Non-pyrotechnic Separation (Acceleration/Clevis Separation)

Operations Requirement:

Simplify vehicle separation design and related ground processing.

Rationale:

Contemporary stage separation hardware and ground processing are complex, hazardous, and eat manpower.

Test and checkout of electrical systems for ignition of pyrotechnic devices is lengthy and wasteful of manpower during repetitive "area clear" operations. STS 51-L preps for mating required a total clock time of 72 hours directly related to separation hardware and pyrotechnics installation and test.

Sample Concept:

The concept of individual vehicle transit to pad and individual erection, suggests the geometric possibility of a vehicle "back-to-back or parallel mating and a separation system requiring no moving parts or pyrotechnics. Examination of the following process is suggested:

(1) Design booster and orbiter propulsion/ acceleration mechanics such that the booster acceleration component exceeds that of the orbiter i.e., the booster wants to outclimb or run ahead of the orbiter.

(2) Erect the booster first. Subsequent rotation of the orbiter to vertical about its landing gear (over the flame trench, onto a thrust butt) may allow automatic attachment of the orbiter to the booster by means of a male/female clevis (or pintle and gudgeon arrangement having no moving parts or pyrotechnics. The orbiter is effectively impaled on the booster.

(3) When the booster propellants are expended, aerodynamic drag provides stage separation.

Technology Requirement:

Detailed examination of aerodynamics and related shock-wave interactions would be necessary to assure validity of concept.

Either a twin-hull booster, an exterior payload bay, parallel mating (or other alternative) will be required to eliminate structural interference of the vehicles during erection of the orbiter.

Technology References:

This document, Section 3.0.

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2.5 PROPULSION

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SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA PROPULSION

- INTEGRATED PROPULSION SYSTEM

P1) • SIMPLIFIED ROBUST PROPULSION SYSTEM

P1.1) • FULLY THROTTLEABLE ENGINES (MULTI-PHASE)

P1.2) • SOFT ENGINE START

P1.3) • TVC BY DELTA THRUST AND/ OR RCS / OR AERO

P1.4) • ONE OXIDIZER / ONE FUEL

ELIMINATE

P 2) o SEPARATE OMS AND RCS

P 3) o HIGH MAINTENANCE TURBOPPUMPS

P 4) o HYDRAULICS

P 5) o HYPERGOLS

P 6) o GN_2 / He ON-BOARD PURGES

P 7) o GN_2 / He PRESSURE SYSTEM

P 8) o GIMBALLED ENGINES

▭ P 9) o EXTENSIVE RECOVERY & REFURBISHMENT

NOTE: ▭

These items were consistent with the preliminary ALS RFP but may not be applicable to current design concepts

PAGE 56 INTENTIONALLY BLANK

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No: P1 **Title**: Simplified Robust Propulsion System

Operations Requirement:

Simplified, integrated, robust propulsion system that uses the same oxidizer and fuel, and integrates the essential elements of:

main propulsion

orbital maneuver/de-orbit

attitude/rendezvous control

Rationale:

Current propulsion systems started with an engine design and then the MPS was built around it.

There is a necessity to simplify and integrate all propulsion systems to radically minimize the supporting operations and maintenance.

Sample Concept:

Fully-throttleable engines/multiphase (see P1.1)

Soft engine start (see P1.2)

TVC by delta thrust and/or RCS/or aero (see P1.3)

One oxidizer/ one fuel (see P1.4)

Eliminate separate OMS and RCS (see P2)

Eliminate high-maintenance turbopumps (see P3)

No hydraulics (see p4)

Technology Requirement:

(See P1.1 through P8)

Technology References:

NASA/RECON (See Volume 5):

87A32466,	87A18475,	87A11334,	87A10698,	86X10270,	86N70079,
86A42731,	86A42620,	85X77367,	85X74308,	85X70592,	85N25389,
85N29965,	85N26862,	85A39670,	85A13519,	84X78616,	84X78036,
84X72894,	84N32430,	84N71351,	84K11473,	84A38153,	84A35137,
83A29534,	83A28693,	82X73602,	82A44488,	79X75706,	78A11082,
74N71316,	74N70964,	74A12920,	74A11559,	73N12847,	
73N12840					

See SGOE/T Study Phase 2 Final Report, Volume 5, Technology References.

See this document, Section 3.0.

No: P1.1 **Title**: Fully Throttleable Engines (multi-phase)

Operations Requirement:

Design and develop main propulsion system rocket engines that are fully throttleable from near 0 to 100%.

Rationale:

The SSMEs can be throttled only from 65% to over 100%. With multiple restart and lower thrust capability, the MPS could be used for orbital maneuvering and de-orbit (OMS); thereby saving cost, weight, and T&C/O of separate OMS systems. For upper stages, this is possibly an alternative to simple pressure-fed engines, but has higher related operations cost, since it doesn't eliminate turbopumps.

Sample Concept:

Use tank-head start phase. Add a percentage of propellant to the chamber with a turbopump to increase mass flow. Gradually delete pressure-fed component to achieve maximum propellant mass flow. Thrust can then be tailored to mission profile to accommodate acceleration requirements.

Technology Requirement:

Must develop:

1. SSME multiple restart capability
   - Spark plug/arc
   - Hot resistor
2. Throttleability
   - Multi-phase concept
     - o Pressure fed
     - o Turbopump assist
     - o Full turbopump
   - Multi-segment toridal chamber
3. MPS propellant acquisition technique for Zero-G restart

Technology References:

NASA/RECON (See Volume 5): 84X10295

See P1.

No: P1.2 **Title**: Soft Engine Start

Operations Requirement:

Revise rocket engine start-transient time specifications to provide significantly lower thrust build-up rate.

Rationale:

Existing SSME rapid start can reduce life expectancy and increase refurbishment frequency of turbopump bearings, seals, and propellant valves.

Sample Concept:

Same as Operations Requirement above.

Technology Requirement:

None

Technology References:

See P1.

No: P1.3 **Title**: TVC by Delta Thrust and/or RCS/or Aero

Operations Requirement:

Provide TVC or some form of vehicle attitude control during MPS operation if gimballed engines are eliminated.

Rationale:

Simplifying the vehicle systems and ground operations by deleting gimballed engines and associated systems requires alternate method of TVC or vehicle attitude control during MPS operation as proposed in Item P1.

Sample Concept:

Using multi-engine concept, and off-center thrust vectors, use differential throttling for trajectory control. Accept less than "normal" TVC angle specifications. Possible use of aerodynamic surfaces, also.

Technology Requirement:

Throttleable engines; see items P1.1 and P2 concepts.

Technology References:

NASA/RECON (See Volume 5):

87N16551,	87N11735,	87A33249,	87A32117,	87A19603,	86X75348,
86A28490,	85X74761,	85X73876,	85N22229,	85A45971,	85A41019,
85A39562,	85A24795,	84X77582,	84X72233,	84X10357,	84N72750,
84N24603,	84N12237,	84K10744,	84K10153,	84A40143,	84A43401,
84A29544,	84A29543,	84A26701,	84A16526,	84A11999,	83A11175

See SGOE/T Study Phase 2 Final Report, Volume 5, Technology References.

No: P1.4 **Title:** One Oxidizer / One Fuel

Operations Requirement:

Simplify propellant procurement, transport, storage, pumping, safety equipment and procedures by designing vehicles using only one oxidizer and one fuel.

Rationale:

Each individual propellant ground system requires its own little army of engineers, technicians, safety, and expensive, hazardous facilities/GSE.

STS has five propellant components, each of which require separate procurement, transport, storage, pumping , GSE, safety, operational procedures, engineers, technicians, etc.

Sample Concept:

Propellant-related ground support operations and the different vehicle systems test and checkout would be immensely simplified if only one oxidizer and one fuel were required.

Technology Requirement:

Development only.

Technology References:

See P1.

No.: P2 **Title:** Eliminate Separate OMS and RCS

Operations Requirement:

Delete OMS and RCS as separate systems from MPS.

Rationale:

If MPS can be utilized for OMS and RCS, it may significantly lighten vehicle and will simplify ground support operations.

Sample Concept:

Use one of MPS engines at greatly reduced throttle for final orbit insertion and de-orbit. This eliminates separate engines, valves, thrust structure and tankage with a modest increase in on-board MPS tankage.

The integrated propulsion system, for ideal simplicity and minimization of "systems" should include, as a design goal, the attitude control functions of an ERS system.

Concept dependent on booster and orbiter having independent propulsion and tankage as proposed in STAS.

Technology Requirement:

1. Develop throttleable MPS; see P1.1 and P2.
2. Develop orbital restart capability
3. Develop Zero-G propellant acquisition techniques

Technology References:

See P1.

No: P3 **Title**: Eliminate High-Maintenance Turbopumps

Operations Requirement:

The ideal requirement is to eliminate high maintenance turbopumps.

Rationale:

Turbopumps are very costly to develop and manufacture: heavy, very high RPM, cavitation-sensitive devices.

Rocket engine cost, refurbishment frequency, refurbishment cost, and T&C/O time consumption are largely driven by turbopump sensitivity.

Pressure-fed engines with plug nozzles are a viable prospect as specific impulse is relatively insensitive to chamber pressure per se.

Sample Concept:

Develop a low-pressure-fed engine in the interest of providing minimum tankage weight and simplifying associated transport and handling GSE. A non-conventional (plug) nozzle will be necessary to shorten length, reduce weight, and compensate for the low-chamber-pressure thrust deficiency of conventional booster nozzles.

An alternative is to develop a turbopump that is robust and essentially maintenance free.

Technology Requirement:

1. Lightest possible PFLB design (competive with turbopump-type vehicle)
2. Pressure-fed injector design
3. Igniter design
4. Plug nozzle design, toroidal thrust chamber, or other concept to shorten nozzle and increase low altitude thrust coefficient.

Technology References:

See P1.

No.: P4 **Title:** No Hydraulics

Operations Requirement:

Provide high thrust actuators for vehicle systems using a system other than hydraulic.

Rationale:

Hydraulic systems are heavy, complex, and plagued with O&M GSE activities. Vehicle and ground support operations would be greatly simplified if simpler, more reliable alternative is developed.

Sample Concept:

State-of-the-art high-torque electric motors coupled to low-friction ball-worm linear actuators and high-leverage mechanical linkage hold promise of great simplification for ground support operations.

Technology Requirement:

Develop motors with ball-worm actuators and self-test status reporting for specific applications.

Technology References:

See P1.3.

No: P5 **Title**: No Hypergols

Operations Requirement:

No hypergols for launch, orbital propulsion, or APU systems.

Rationale:

A very significant quantity of non-productive manhours occurs during each flow for "area clear" required during hazardous opening/entry/operation of OMS and RCS orbiter systems. There is also a snowballing effect in facilities and O&M requirements for special ventilation, scrubbers and a multitude of safety equipment, including a small army to use and maintain SCAPE (self-contained atmospheric protective ensemble) suits. Further, a pound of MMH hypergol costs about \$10.00, and N_2O_4 costs \$.75/lb. whereas, LOX costs \$0.04/lb; RP-1 - \$0.21/lb; C_3H_8 - \$0.27/lb and CH_4 - \$0.71/lb.

Sample Concept:

Utilize portion of main propulsion for OMS. Adapt Space Station O_2/H_2 thruster for airborne/orbital RCS.

Technology Requirement:

Develop systems using prime propellants for OMS, RCS, and APU applications. (See P1.)

Technology References:

(See P1.)

No: P6 **Title**: No GN_2/He On-board Purges

Operations Requirement:

Delete launch vehicle on-board GN_2 and H_e purge systems.

Rationale:

Subject systems add weight to vehicle and electro/mechanical/pneumatics require special small O&M army and much time for ground processing and launch.

Sample Concept:

Eliminate sources of hazardous fluid leaks (and consequently purges) such as bolted flanges with seals, flared fittings, etc. Utilize welded or brazed assembly techniques and/or Nitinol compression fittings.

Use lightweight airborne mass spectrometer with sensing lines or design vehicle with multitude of very small, lightweight electronic fuel and oxidizer sensors capable of verifying leak-tight vehicle configuration. Load fuel first. Verify system leak-free, then load oxidizer.

Technology Requirement:

Develop MPS engine requiring no purge prior to firing in atmosphere.

Lightweight mass spectrometer for launch and flight environment.

Consider Nitinol fittings, particularly for hard-to-reach connections.

Technology References:

NASA/RECON (See Volume 5):
86X71562, 86N21849, 85X76796, 85X76476, 85X73181, 85N21386, 85A47011, 84K10941, 84A42759, 82X78166

See SGOE/T Study Phase 2 Final Report, Volume 5, Technology References.

This Document, Section 3.0

No: P7 **Title**: No GN_2/H_e Pressure Systems

Operations Requirement:

Delete GN_2 and H_e valves control plumbing and propellant tankage pressure systems.

Rationale:

Elimination of GN_2 and H_e storage bottles, supply valves, manifolds, plumbing, and multiple test and checkout, will significantly lighten the vehicle, and simplify and speed-up ground support operations.

Sample Concept:

Provide electromechanical valve actuators with electrical self-test/status capability. Propellant tank prepressurization at launch provided from cryo propellant boil-off with vent valve cycling as needed. Use gas generator or engine hot gas bleed/heat exchanger during flight a la STS.

Technology Requirement:

Design application of existing technology. Innovative vehicle design.

Technology References:

This document, Section 3.0.

No.: P8 **Title**: No Gimballed Engines

Operations Requirement:

Devise thrust vector or vehicle attitude control system which eliminates need for gimballed engines and associated hydraulics, seals, pivots, bellows, etc.

Rationale:

Gimbal systems are expensive and heavy, and add a severe burden of O&M, and test and checkout to ground support operations.

Sample Concept:

Using multi-engine concept, and off-center thrust vectors, use differential throttling for trajectory control. Accept less than "normal" TVC angle specifications. Reexamine the flight dynamics models to determine if the TVC requirements can be reduced to a point where methods other than gimballing would be acceptable.

Technology Requirement:

Throttleable engines; see Items P1.1 and P1.3 TVC concepts.

Technology References:

See P1.3.

No.: P9 **Title:** No Extensive Recovery & Refurbishment

Operational Requirement:

Eliminate crash and salvage operations similar to STS SRB. Any land recovery should be benign and easily transportable.

Rationale:

Experience with the STS SRB's has proven it is not cost effective. Any water recovery with propulsion/avionics units would be even worse.

Size and weight of recovery module dictate firm landing site with good road access. A typical module of 50,000 pounds, the size of a small two-story house, presents a severe transportation problem.

Environmental problems also exist with residual hypergols onboard with land recovery.

Sample Concept:

Expendable or runway recovery rather than parachute type recovery.

Technology Requirement:

Simple integrated propulsion system design than can be built cheaply enough to be a throwaway. (See P1).

Technology References:

See P1.

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2.6 FACILITIES AND SUPPORT EQUIPMENT

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SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA FACILITIES & SUPPORT EQUIPMENT

L 1) ● 100% COMPUTER CONNECTIVITY

● AUTOMATION

- L 2) ● ELECTRONIC OMI's
- L 3) ● TEXT AND GRAPHICAL DATA ACQUISITION
- L 4) ● TEST REQUIREMENT VERIFICATION

● STAGE ASSEMBLY

- L 5) ● INITIAL NEAR LAUNCH CENTER
- L 5) ● FINAL AT LAUNCH CENTER

▭ L 6) ● HORIZONTAL PROCESSING

- ▭ L 7) ● HORIZONTAL TRANSPORT

● PAYLOADS

- L 10) ● ONE AUTONOMOUS CONTAINER

● PAD

- L 8) ● BARREN PAD
- ▭ L 9) ● ERECT / MATE STAGES AT PAD
- L 8.1) ● DEEP WATER EXHAUST BUFFER
- L 8) ● LIGHTNING / LIGHTING TOWER
- L 8.2) ● FLY-AWAY CONNECTS ONLY
- L 8) ● PROPELLANT FARM
- ▭ L 6) ● PAVED TOW - WAY

● MOBILE EQUIPMENT

- ▭ L 6 ● STANDARD AIRCRAFT TUG
- ▭ L 6 ● STRAP-ON WHEELED DOLLIES
- ▭ L 6 ● MOBILE CRANE

● BUILDINGS

- ▭ L 6 ● HORIZONTAL PROCESSING FACILITY

ELIMINATE

○ AUTOMATION

- L 1) ○ ISOLATED DATABASES
- L 2) ○ PAPERWORK RELATED TO TEST
- L 4) ○ REQUIREMENTS VERIFICATION
- L 3) ○ PRINTED TRANSFER OF TEXT / DATA

L 10) ○ PAYLOAD / VEHICLE INTEGRATION VERIFICATION TESTING

▭ L 9) ○ LIFTING VEHICLES CLEAR OF GROUND

○ PAD EQUIPMENT

- L 4) ○ HARDWIRE CONNECTS
- L 8.4) ○ ACCESS STRUCTURES
- L 8.3) ○ SWINGARMS
- L 8) ○ RETRACTING UMBILICALS
- L 8.5) ○ T-O HOLD-DOWN
- L 8.6) ○ DELUGE WATER
- L 8.6) ○ SOUND SUPPRESSION WATER
- L 8.1) ○ FLAME TRENCH / DEFLECTOR
- L 8.7) ○ ECS
- P 6) ○ He / GN_2 STORAGE
- E) ○ GROUND POWER
- ▭ L 7) ○ CRAWLER WAY

○ MOBILE EQUIPMENT

- ▭ L 7) ○ CRAWLER / TRANSPORTER
- ▭ L 7) ○ MOBILE LAUNCH PLATFORM

○ BUILDINGS

- ▭ L 6) ○ VAB
- ▭ L 6) ○ VPF
- ▭ L 6) ○ RPSF

NOTE: ▭

These items were consistent with the preliminary ALS RFP but may not be applicable to current design concepts

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No: L1 **Title**: 100% Computer Connectivity

Operations Requirement:

All computers associated in any manner with operations, flight, or ground must provide and maintain complete connecting (bridging).

Rationale:

The vast amount of data required to support and maintain any operational system requires maintenace of maximum efficiency.

Paperwork currently requires a large portion of the allocated operation budget. A potential reduction of 5% of the total LCC can be achieved by automation of paperwork. Isolated databases must be eliminated to accomplish this.

Sample Concept:

Utilization of commercial DBMS which support heterogenous file transfer and data import and export via MIL-STD-1840A.

Technology Requirement:

Distributed database management systems providing for flexible computer connectivity.

Technology References:

NASA/RECON (See Volume 5): 86N27948, 84N31144, 84N23296, 84N21107

DIALOG: 2034798, 2011582, 2011580, 1979702, 1978939, 1964804, 1947009, 1877817, 1876159, 1868213, 1852081, 1842967, 1836336, 1823013, 1380555

PAGE 76 INTENTIONALLY BLANK

No: L2 **Title**: Automated Electronic OMI's

Operations Requirement:

Operational and support procedures should be computer-based and maintained.

Rationale:

Conventional hard copy procedures are difficult and expensive to maintain. The manual update, copy and distribution of procedures does not provide for cost effective efficient operations. The lack of procedural discipline results in many errors. Automated procedures would control procedural sequence, data recording and associated support data presentation.

Sample Concept:

Procedures to be received from vendor in MIL-STD-1840A including graphics. These data then to be processed into an operational site procedure format. As procedures are scheduled for performance, the test conductor calls them up on on his terminal and follows display of instructions and sequences.

Technology Requirement:

Procedure authoring and update, standardize text and graphics formats.

Technology References:

NASA/RECON (See Volume 5): 86N21206, 86N20477, 85N27754, 85N27121, 85N24835, 85N12793, 85N11603, 85A37968, 84N21406

DIALOG: 2037337, 2008924, 1783653, 1713486, 1670611, 1593032, 1502409, 1381439, 1335095, 1401285, 1221478

No.: L3 **Title:** Text and Graphical Data Acquisition

Operations Requirement:

Import and export of text and graphics requires that data formats be standardized. Eliminate hard copy transfer of text and data for information purposes and approvals.

Rationale:

The large volume of operations and support data is currently generated, maintained, and distributed in hard copy form and is highly labor intensive.

Sample Concept:

Text and graphics data imported and exported via MIL-STD-1840A.

Technology Requirement:

Text and graphics standards: MIL-STD-1840A

Technology References:

NASA/RECON (See Volume 5): 86N17218, 84N24236

DIALOG: 2037208, 2027585

No: L4 **Title**: Automatic Test Requirements Verification

Operations Requirement:

Test requirements verification must be automatically correlated with the completion of the associated procedures.

Rationale:

Current manual method is inefficient, inadequate, and error prone.

Sample Concept:

An automated OMI is truly paperless, with sequence execution controlled by the scheduling systems and should track the completion of each procedure and task. As each task is completed, without error, or retest accomplished, all associated test requirements are automatically verified.

Technology Requirement:

Distributed data processing, networking, computer/data connectivity.

Technology References:

NASA/RECON (See Volume 5): 85N30000, 85A33722, 84N33290, 84A26738, 82N23042

See also L2.

No.: L5 **Title:** Final Stage Assembly at Launch Site

Operations Requirement:

Perform initial stage assembly at manufacturing facility near Launch Center.

Perform all stage assembly, refurbishment and T&C/O in one low-bay building at the launch center; including horizontal installation of autonomous payload.

Rationale:

Simplifies transportation from manufacturing facilities to Launch Center.

Simplifies and minimizes assembly and T&C/O facilities. Eliminates a separate high-bay vehicle assembly building and large overhead lift-to-mate GSE.

More efficient use of personnel who can be cross-utilized for assembly and for checkout. Proximity of manufacturing facility to Launch Center further enables cross-utilization.

Sample Concept:

Reduce launch support facilities to three major categories:

1. Stage processing, T&C/O
2. Payload preparation
3. Launcher/pad

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

No: L6 **Title:** Horizontal Processing: Horizontal Transport

Operations Requirement:

Provide combination of flight vehicle design, inter-related ground processing requirements, and support facilities resulting in the simplest, least costly repetitive launch cycle. Horizontal mode proposed by this study.

GROUND PROCESSING MODE COMPARISON

Rationale

	VERTICAL	HORIZONTAL
Transportation	- complex transporter and self-leveling platform - greater clearance requirements	+ strap-on wheeled dolly or integral landing gear for recoverables
Handling	- requires extensive use of hoists/cranes/slings and strongbacks - vehicle must provide multipurpose attach points for element rotation - flight vehicles "in the air" during rotation, lift, & mate. pendulum effect creates tedious & hazardous operations.	+ individual element rotation not required prior to integration at pad + concept utilizes mobile crane with power-down controls for rotation (simplified capital equipment investment and O & M + flight vehicles always in contact with ground until launch
L V integration	- complex mate/demate operations	+ stage nesting or parallel mate reduces handling, simplified mate/demate
Rollout	- vehicle stacked on launch platform which must be mobile and self-leveling	+ rollout on gear or dollies - requires L V erector system at pad
Operational Access (vehicle)	O P F: + same as horizontal POST O P F: - circumferential access - provides diminished continuous vehicle access - increases logistical response - use of elevators or hoists/cranes - increases technicians response time - requires multiple entry access kits (vert., horiz.) (manufactured horiz.) - greater number of "hazardous area" clears due to overhead hoisting	POST O P F: + longitudinal access - substantial continuous vehicle access + decreases logistical response + increases operations efficiency - unique vehicle access kits required + conducive to parallel operations
Facilities	- requires tall structures with adequate "bay to bay" clearances - requires complex access platforms (extend/retract type) - increases O & M - requires multiple vehicle relocations: receipt, c/o and standard integration - requires crawlerway or equiv	+ barren pad; catastrophic damage greatly minimized + synergistic to production plant layout & application (common handling equip.) + reduces number of vehicle motions + lessens O & M + no separate vehicle integration facility (VAB) needed - requires paved roadway

L6 (Continued)

	VERTICAL	HORIZONTAL
Payloads	+ capable of handling vertical payloads + SIS non-DOD P/L's thru SIS-33 were: 80 horizontal 106 vertical + high orbit P/L's save critical weight with vertical processing + better payload access	- cannot handle vertical payloads + analysis of non-DoD SIS P/L's to-date shows the horizontal/vertical ratio could have been 149/37 for ALS instead of the 80/106 actual for SIS - high orbit P/L's require innovative horizontal support + STAS groundrule G-6, "for new systems, assume no payload change-out at the pad."

CONCLUSIONS:

- o **Horizontal vehicle processing is more efficient**
- o **Stages must be self transporting (integral landing gear) or utilize strap on dollies**

Sample Concept:

Horizontal T&C/O processing concept requires the following full-cycle ground operations description to demonstrate viability.

GROUND PROCESSING SEQUENCE

1. Flyback: -- booster lands at post-launch post-mission intervals at the SLF or equal.
2. Flyback: -- Stages safed and towed on integral landing gear to deservice/ refurbish/launch preparation. Facilities (OPF or equal).
3. Stages assembled/serviced and prepared for launch.
4. Autonomous payload canister/cocoon/pallet installed in orbiter in horizontal attitude in same facility by overhead crane (OPF or equal).
5. Stages towed in horizontal attitude on integral landing gear or wheeled dollies to launch pad and rotated to vertical about the aft wheels onto lift-off-style aft umbilical Q/D carriers, using specially selected mobile crane having power-down hook and boom systems and controls. Stages attached side-by-side. Any technician access via special mobile access manlift. Stage max. length limited by mobile crane boom-length/load radius capability. 180-ft. maximum stage length considered feasible state-of-art with existing KSC equipment.
6. Launch

Technology Requirement:

1. Development of moderate-size stages with integral landing gear.
2. Radically simplified, autonomous (self-test/evaluation; self-contained electrical power) stages.
3. Radically simplied, "barren pad".
4. Acceptance/development of mobile crane usage for flight hardware based on highly satisfactory operational history at KSC.

Technology References:

NASA/RECON (See Volume 5): 86X76652, 85N16967, 85N16927, 85N12001, 85A13163, 85A12988, 84X74531, 84N75063, 84A44153, 83X71371, 83A31196, 81A26524, 80X72115

No: L7 **Title**: Horizontal Transport of Individual Stages to Pad

Operations Requirement:

Eliminate LV rotation, high-lift VAB scenario, and the related extensive GSE and GSO army. Provide simple, rapid transit of flight stages through the ground processing cycle: from landing site (if recoverable) or stage assembly facility (if expendable), to processing facility, to launch pad.

Rationale:

Conventional rotation, lift, and mate in the VAB requires large mobilization for complex, interrelated GSO, equipment, and personnel.

The operational efficiency and cost reduction potential of this concept are strongly dependent on capability to insert the payload cocoon as late as practical in the flow, i.e., immediately before vehicle transfer to pad. Use of landing gear or strap-on dollies and aircraft tug-type operation eliminate the need for large, O&M-intensive crawler-transporter (CT) and mobile launcher platform (MLP), and allow rapid transit.

Sample Concept:

Perform T&C/O of all stages in horizontal attitude. Only one set and type of access GSE is required. Complete T&C/O, roll individual stages to pad, rotate to vertical with mobile crane and engage stage-mate clevis. Simplified vehicle and pad are key to reduced time at pad. If access for vertical payload insertion were made mandatory, it would cause the return of costly structures and O&M army and compromise the "barren-pad" concept.

Transit via integral landing gear or strap-on dollies also allows individual stage transfer to the pad and, individual rotation - to - vertical about the wheels using a mobile crane and maintaining ground contact. This would provide the following benefits:

(1) Rapid/timely transfer of individual stages to pad.

(2) Minimum payload ground loiter time subsequent to insertion in vehicle.

(3) Requires roadway capable of supporting stages individually, but crawler-transporter and mobile launcher platform are not required; gravelled crawlerway and repetitive dragging / smoothing not necessary.

(4) Erection GSE greatly simplified. At KSC mobile cranes are routinely maintained and available. Rotation to vertical can be accomplished without lifting flight vehicle from ground; assures full control of vehicle while "on-the-hook", greatly improving safety of the operation.

(5) For a ground processing scenario limited to horizontal vehicle handling, transit to pad can be either individual or piggyback. The concept of individual stage transport promises a lighter booster.

Technology Requirement:

Simplified launch vehicle and greatly revised design and operations philosophy aimed at eliminating all possible GSE and ground support operations.

Proposed pad and vehicle are very much simplified from conventional concepts. Vehicle simplification, as proposed in other items herein, eliminates dependence on multi-level vehicle access/connections provided by swingarms.

Technology References:

This document, Section 3.0.

No.: L8 **Title:** Barren Pad

Operational Requirement:

Barren pad with essentially no GSE or supporting structures.

Rationale:

A major contributor to ground operations cost is the complexity of GSE and structures at the pad which require constant maintenance and/or refurbishment and modifications. Each of which require small armies of supporting personnel (engineers, technicians, mechanics, clerks, etc.)

Sample Concept:

A "barren pad" would have the following essentials:

* Simple raised concrete structure
* Deep water exhaust buffer
* Lightning/lighting tower
* Propellant farm
* Mobile crane (as required)
* Flyaway propellant connections
* Wireless (infrared/optical/RF) control & data connections

It would not have:

* Access structures
* Swingarms
* Retracting umbilicals
* T-0 holddown
* Firebrick flame trench and deflectors
* Deluge water system
* Sound suppression water system
* Large pad terminal connection room
* Ground power system and related GSE
* ECS GSE
* Vehicle system GSE
* Hardwire connections to vehicle
* Office and shop facilities

Technology Requirement:

Development only.

Technology References:

This document, Section 3.0.

No: L8.1 **Title**: Deep Water Exhaust Buffer

Operations Requirement:

Simplify flame trench and deflector to eliminate frequent costly maintenance.

Rationale:

Replacement of firebrick, major refurbishment at repetitive intervals, and consistently high structural erosion of flame deflectors is costly. These should be greatly reduced or nearly eliminated.

Sample Concept:

Construct the new pad with typically deep pilings and footers, although not necessary to support weight of MLPs and towers (they aren't used in proposed pad). Dredge very deep pond at base of flame trench (40-60 ft. deep). Connect by low maintenance canal to banana river or nearby body of water. Deep water will serve to quench exhaust and act as flame deflector.

Technology Requirement:

Investigate water depth requirement as function of thrust level and rocket engine geometry.

Technology References:

This document, Section 3.0.

No: L8.2 **Title**: Flyaway Connects Only - No Retracting Umbilical Carrier Plates

Operations Requirement:

Provide simplified vehicle umbilical disconnect systems.

Rationale:

Contemporary quick-disconnect umbilical carriers are very complex, suceptible to launch-damage, and manpower-intensive for test and checkout. Post-launch refurbishment is repetitive, costly, and time consuming.

Sample Concept:

Proposed pad has no vehicle access towers, swingarms or retracting umbilical carrier plates. All hard connects to the vehicle (essentially propellant lines) are vertical lift-off type with simple, gravity operated protective covers for QDs and the carrier plate.

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

No: L8.3 **Title**: No Swingarms

Operations Requirement:

Simplify or eliminate all swingarms with the related ground support operations, equipment, and structures to dramatically reduce repetitive costs. Eliminate repetitive tests and checkout at pad and post launch refurbishment.

Rationale:

Contemporary swingarms are expensive, complex, O&M intensive, and launch critical systems.

Sample Concept:

Proposed pad and vehicle are very much simplified compared to conventional concepts. Vehicle simplification, as proposed in other items herein, eliminates dependence on multi-level vehicle access/connections provided by swingarms. Payload canister inserted during T&C/O prior to transfer to pad. Passenger access via special mobile manlift.

Technology Requirement:

Concept dependent on development of simplified vehicle by related technology developments proposed in other items herein.

Technology References:

This document, Section 3.0.

No: L8.4 **Title**: No Vehicle or Payload Access Structure

Operations Requirement:

No vehicle or payload access structure.

Minimize vehicle resident time at pad. Rollout, erect, fuel, verify satisfactory self-test, launch.

Limited LRU changeout capability at pad (boattail).

Rationale:

Current STS requires two weeks or more at the pad for extensive interface systems test and checkout, payload access for O&M, vertical P/L insertion, closeout and all-systems verifications. This time period and tedious process is not acceptable for reduced cost and high launch rate.

Sample Concept:

Mandatory access for vertical payload insertion would return the likelihood of costly structures and O&M army compromising the "barren-pad" concept.

Technology Requirement:

1. Consideration of mobile payload transporter with elevated lift capability, if vertical access is absolutely mandatory.

2. Mobile crane capability at KSC is historically and operationally well established, possesses excellent safety record, is highly reliable, and flexible, and falsely underrated for operational use. Vehicle, payload, and passenger support using some form of mobile crane-adapted system should be considered to retain "barren-pad" concept.

Technology References:

This document, Section 3.0.

No: L8.5 **Title**: Simplified Holddown/release

Operations Requirement:

Greatly simplify vehicle holddown systems at pad.

Rationale:

Holddown system of some kind is mandatory to restrain vehicle in high winds and to stabilize motion during engine start. Existing method is costly, dangerous, time-consuming, and not required for continuously variable thrust.

Sample Concept:

Eliminate explosive aspect of bolts, and ultra-high bolt torqueing. Nitinol mechanisms hold promise of holddown/release systems having no pyrotechnics or moving-linkage mechanisms.

Technology Requirement:

Innovative holddown and release mechanism using Nitinol technology/mechanism development or equal.

Technology References:

This document, Section 3.0.

No: L8.6 **Title**: No Deluge or Sound Suppression Water

Operations Requirement:

Eliminate very extensive facilities, personnel, test and checkout procedures, and costly O&M of pad water systems.

Rationale:

Gross simplification of launch pad facilities and operations is essential to reduce cost-to-orbit by factor of 10.

Sample Concept:

Proposed pad has no towers or access structures other than lightning-arrest tower(s).

Firex/deluge water necessary to protect swing arm hydraulics, propellants, pneumatics, electrical cabinets and tower/MLP deck are all eliminated by the "barren pad" concept.

Sound suppression water of the STS system is necessary to protect the launch vehicle from the low frequency, high energy acoustics generated by the SRBs.

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

No: L8.7 **Title**: No Pad ECS

Operations Requirement:

Delete extensive costly equipment and personnel providing internal pad structures GN2 purge and pre-launch pressurization. Delete similar systems providing vehicle ECS.

Rationale:

These are costly in O&M personnel and test/checkout/pre-launch validation time, and are not necessary in the proposed "barren pad".

Sample Concept:

No vehicle on-board work is done at the pad other than erection, propellant loading and communications/ controls connect/ positioning. Therefore, no ground-provided vehicle ECS is required. Payload canister is autonomous (manned or unmanned).

Proposed pad blast area does not include offices, shops, restrooms, or routinely occupied areas; only propellant lines, communications/controls and hold-down/umbilical access tunnels.

Technology Requirement:

None.

Technology References:

This document, Section 3.0.

No: L9 **Title**: Erect/Mate Stages at Pad

Operations Requirement:

Eliminate complex rotation, mate, and associated GSE and bridge cranes in VAB vehicle-mating scenario. Also, eliminate need to transport very large, delicate, awkward assembly to launch pad.

Rationale:

Mating remotely from launch center requires army of men and GSE for complex lifting/rotation harness, bridge cranes, MLP, C/T, platform retraction and the very expensive, labor intensive O&M "tree" necessary to support all this equipment.

Sample Concept:

"Barren Pad" equipped with very simple aft thrust/butt stands on side of flame trench wall. Individual stages rolled relatively quickly to pad on integral landing gear (reusable vehicles). Individual stages rotated to vertical from opposite sides of flame trench using large mobile crane with additional winch for vehicle horizontal restraint line. Vehicle "nesting" concept greatly simplifies pad configuration.

One of the prime limitations of mobile crane support is the payload "swinging pendulum" effect. This same effect is also a serious operational hazard with bridge cranes, e.g., KSC/VAB. mobile cranes have been successfully used in place of the MDD to lift orbiters for mate/demate with the SCA on four occasions. inability to restrain the load pendulum resulted in severe wind-speed limitations during those operations. Rotationabout landing ggear or single axle dolly can retain vehicle ground contact at all times and eliminate the pendulum hazard normally associated with both bridge and mobile cranes.

Any large industrial facility (such as a major launch center) routinely requires large mobile crane support for a multitude of logistics and O&M tasks. Using such a system (carefully selected for capability) for vehicle erection at the launch center is like acquiring an erection system virtually for "free".

Further simplification can result from booster/orbiter auto-mate of clevis-type fittings secured by weight or acceleration forces in place of explosive bolts. A special mobile vehicle can be designed to provide passenger access to launch vehicle subsequent to propellant loading.

Technology Requirement:

Development only.

Technology References:

This document, Section 3.0.

No: L10 **Title**: Payloads: Standard Autonomous Cargo Container

Operations Requirement:

Provide only simple mechanical interface between launch vehicle and payload.

Rationale:

Orbiter payload bay modifications and payload flight support equipment software modifications are among the most time consuming ground support operations.

Sample Concept:

Develop a payload bay module consisting of orbiter-universal strongback and environmental cover (as needed) that has internal capability to support payload electrical, environmental, and communications requirements from loading until orbital placement. This philosophy is also applicable to man-carrying orbital delivery module with life support systems. Concept is dependent upon forcing payload designers to accommodate the launch vehicle rather than vice-versa.

Technology Requirement:

Longer-life, more reliable (high density) fuel cells or other source to support payload module. (See E1).

Technology References:

NASA/RECON (See Volume 5): 86A14382, 84A11721, 78A51985, 76N27347

See also E1.

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3.0 SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CONCEPT

(To be completed during Phase 3)